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التاريـــخ: / /

نموذج رقم (١٨)
اقرار والتزام بقوانين الجامعة الأردنية وأنظمتها وتعليماتها لطلبة الماجستير

أنا الطالب: شادي علي محمود العبادي الرقم الجامعي: ٨٠٩٠٠٥٩

التخصص: علم الحاسوب الكلية: الملك عبدالله لتكنولوجيا المعلومات

اعلن بأنني قد التزمت بقوانين الجامعة الأردنية وأنظمتها وتعليماتها وقراراتها السارية المفعول المتعلقة باعداد رسائل الماجستير والدكتوراة عندما قمت شخصيا" باعداد رسالتي / اطروحتي بعنوان:

modified contention window mechanism for IEEE 802.11 Distributed coordination function

آلية إطار تنافس معدلة لدالة التنسيق الموزع في معيار ٨٠٢,١١

وذلك بما ينسجم مع الأمانة العلمية المتعارف عليها في كتابة الرسائل والأطاريح العلمية. كما أنني أعلن بأن رسالتي /اطروحتي هذه غير منقولة أو مستلة من رسائل أو أطاريح أو كتب أو أبحاث أو أي منشورات علمية تم نشرها أو تخزينها في أي وسيلة اعلامية، وتأسيسا" على ما تقدم فانني أتحمل المسؤولية بأنواعها كافة فيما لو تبين غير ذلك بما فيه حق مجلس العمداء في الجامعة الأردنية بالغاء قرار منحي الدرجة العلمية التي حصلت عليها وسحب شهادة التخرج مني بعد صدورها دون أن يكون لي أي حق في التظلم أو الاعتراض أو الطعن بأي صورة كانت في القرار الصادر عن مجلس العمداء بهذا الصدد.

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Modified Contention Window Mechanism for IEEE 802.11 Distributed Coordination Function

By:

Thaeer Ali Mahmoud Kobbaey

Supervisor:

Dr. Abdel Latif Abu-Dalhoum

This Thesis is Submitted in Partial Fulfillment of the Requirements for the Master's Degree of Science in Computer Science

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COMMITTEE DECISION

This Thesis/Dissertation (MODIFIED CONTENTION WINDOW MECHANISM FOR IEEE 802.11 DISTRIBUTED COORDINATION FUNCTION) was successfully Defended and Approved on 27/7/2011.

Examination Committee		Signature
Dr. Abed Latif Abu Dalhoum Assoc. Prof. of Genetic Algorithms & Complex Systems.	(Supervisor)	....
Dr. Azzam Sleit Assoc. Prof. of Spatial Database	(Member)	....
Dr. Saher Manaseer Assist. Prof. of Wireless Networks	(Member)	....
Dr. Ahmad Al Omari Assist. Prof. of Computer & Network Security (Applied Science University)	(Member)	....

DEDICATION

TO MY PARENTS; YOUR UNCONDITIONAL LOVE AND SUPPORT NO MATTER THE CIRCUMSTANCES HAS MADE ME WHO I'M NOW……

TO MY FIANCÉE WHOM HER LOVE AND SUPPORT GAVE ME THE COURAGE AND DETERMINATION TO GO ON……

TO MY BROTHERS, SISTERS IN LAW AND MY NIECE……

TO MY ENTIRE FAMILY, FRIENDS, COLLEAGUES AND PROFESSORS……

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LIST OF ABBREVIATIONS

ACK	: Acknowledgment.
ACW	: Adaptive Contention Window Scheme.
AHBCWC	: Adaptive History Based Contention Window Control.
AP	: Access Point.
BEB	: Binary Exponential Backoff.
BSS	: Basic Service Set.
CBR	: Constant Bit Rate.
CIFS	: Collision Inter Frame Space.
CS	: Channel Status.
CSMA	: Carrier Sense Multiple Access.
CSMA/CA	: Carrier Sense Multiple Access with Collision Avoidance.
CSMA/CD	: Carrier Sense Multiple Access with Collision Detection.
CTS	: Clear To Send.
CW	: Contention Window.
CWmax	: CW Maximum; the maximum value of the Contention Window.
CWmin	: CW Minimum; the minimum value of the Contention Window.
DCF	: Distributed Coordination Function.
DCWA	: Determinist Contention Window Algorithm.
DIFS	: DCF Inter Frame Space.
DILD	: Double Increment, Linear Decrement.

EIED	: Exponential Increment, Exponential Decrement.
EIFS	: Extended Inter Frame Space.
GUI	: Graphical User Interface.
HBCWC	: History Based CW Control.
IBSS	: Independent Basic Service Set.
IEEE	: Institute of Electrical and Electronics Engineers.
IFS	: Inter Frame Space.
Kbps	: Kilobytes per second.
MAC	: Medium Access Control.
MACA	: Multiple Access Collision Avoidance.
MACAW	: Multiple Access Collision Avoidance for Wireless.
MILD	: Multiple Increase, Linear Decrease.
NAV	: Network Allocation Vector.
OS	: Operating System.
PCF	: Point Coordination Function.
PDR	: Packet Delivery Ratio.
PHY	: Physical layer
PIFS	: PCF Inter Frame Space.
PPS	: Packets Per Second.
QoS	: Quality of Services.
RAM	: Random Access Memory.
RF:	: Retransmission Factor.

RTS : Request To Send.

SIFS : Short Inter Frame Space.

WLAN : Wireless Local Area Network.

WMAN : Wireless Metropolitan Area Network.

WPAN : Wireless Personal Area Network.

WWAN : Wireless Wide Area Network.

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Abstract

A Wireless Local Area Network (WLAN) is a group of connected stations that communicate with each other through emissions of electromagnetic energy using the air as a medium; the distributed nature of the wireless network and the nature of its physical medium triggered the need to regulate and control the medium access by stations.

The IEEE 802.11 standard implies a Distributed Coordination Function (DCF) as the fundamental access method in Wireless Networks; the function uses a Binary Exponential Backoff (BEB) mechanism to regulate the channel access and to reduce the probabilities of collisions by controlling the size of the Contention Window (CW); BEB suffers from many limitations which affect the performance of DCF.

This thesis proposes a modified CW mechanism that improves the performance of DCF by solving the problems in BEB; simulation results shows that the proposed mechanism was able to reduce the Average End to End Delay and the Average Jitter. However the proposed mechanism suffers a single limitation which is increasing the packets dropped due to retransmission limit rate, such limitation reduces the performance of the proposed mechanism regarding the throughput; solving that problem is highlighted as the future work to improve the performance of the proposed mechanism.

CHAPTER ONE

INTRODUCTION

The term Wireless Networks refers to any type of connection between several stations or locations while relying on electromagnetic waves as a physical medium of communication rather than cables or wires (Goldsmith, 2005) (Flickenger, 2002).

Norman Abramson has introduced the world's first Wireless Network back in 1971 (Abramson, 1971), nowadays Wireless Networks became an integral component in every house, classroom, company and institute around the globe. The main factor behind such tremendous popularity rise is the unique characteristics of Wireless Networks; the huge development in laptops, notebooks and mobile technology provided new types of stations that favor the ease of installation provided by wireless networks which requires no cabling or special equipment. In addition to the ease of installation; wireless networks are able to cover long distances without the need for cables which will reduce the costs of network installation. Another clear advantage of wireless networks would clearly be noticed when installing the Network in places where it is hard to use cables, such as; historical ancient places, a university campus, airports and public areas.

Wireless Local Area Network (WLAN) is a type of wireless networks that connects stations together in a local coverage area; it is the most used type of wireless networks around the world. Due to increased popularity of WLAN's the need for a universal standard and specifications for WLAN's emerged, in 1992 the Institute of Electrical and

Electronics Engineers (IEEE) project 802 issued the IEEE 802.11 standard (Hiertz et al., 2010); the standard (IEEE, 1999) includes detailed specifications for Media Access Control (MAC) and Physical (PHY) layer in WLAN's.

According to the standard the WLAN's PHY media is shared by all stations and it has a limited cover range. Using a shared media as a physical carrier (channel) implies providing a method to regulate and control how channels can access the station, it also implies providing a method to prevent, detect or avoid collisions that occur when two or more stations tries to access the channel at the same time. The MAC sub layer provides channel access using a Multiple Access Control protocol which controls and regulates how several stations can access the shared channel.

The architecture of MAC sub layer in IEEE 802.11 standard which is shown in Figure 1 (IEEE, 1999) consists of two main functions to regulate and control the wireless channel access; the optional Point Coordination Function (PCF) which is used in the infrastructure WLAN's and the Distributed Coordination Function (DCF) which is used in Ad Hoc WLAN's. According to the standard DCF is the basic access method.

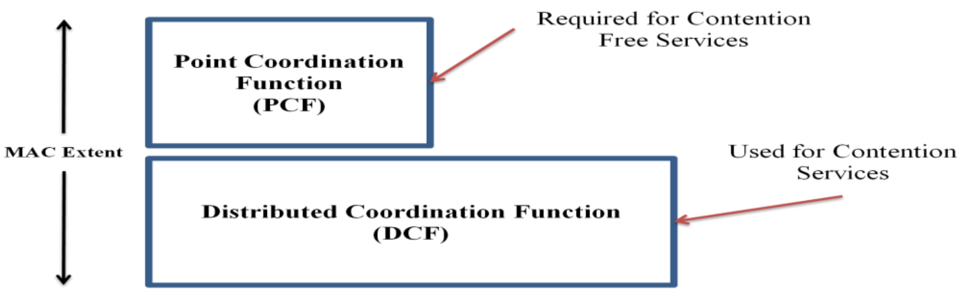

Figure 1: The Architecture of MAC in 802.11.

PCF will not be further discussed since this thesis proposes a modified Contention Window (CW) mechanism for DCF.

DCF implies a Carrier Sense Multiple Access with collision Avoidance (CSMA/CA) access mechanism to control the channel access and reduce the probabilities of collisions. CSMA/CA implies that stations with desire to transmit must sense the physical medium (channel) first and verify if the channel is idle for a predetermined period of time equal to the value of the backoff timer. To reduce collisions probability CSMA/CA implies a Binary Exponential Backoff Algorithm (BEB) to update the backoff timer value with a random number obtained from the range]0, CW+1]. The 802.11 BEB exponentially increases the size of CW when collision occurs and resets the value of CW to the minimum value in case of a successful transmission.

1.1 Problem Statement:

The current CW control mechanism in BEB suffers many problems which eventually affect the performance of DCF and decrease the channel access utilization. The CW control mechanism in BEB suffers the following problems:

I. Problem. 1: Setting the initial size of CW to the minimum.

II. Problem. 2: The exponential increase of the CW.

III. Problem. 3: The fairness problem.

Such problems drop off the performance of DCF, increase the delay and somehow increase the number of collisions which reduces the channel access utilization.

1.2 Thesis Contribution:

This thesis proposes a modified CW control mechanism to solve the problems in the current used CW control in BEB; furthermore the modified mechanism presented in this Thesis aims to:

I. Reduce the probabilities of a collision in the first transmission and the first retransmission after a collision

II. Reduce the average end to end delay.

III. Provide fair and equal channel access chances for all stations.

In this thesis the proposed CW control mechanism is implemented in theory and in simulation using different scenarios to reflect different network conditions. Both the Modified Mechanism and the 802.11 BEB have been tested in simulation. The simulation results are used to evaluate the performance of the proposed mechanism versus the default mechanism.

1.3 Thesis Organization:

The thesis is arranged as follows. Chapter Two is a literature review of the essential background for the topics that concern the work included in this Thesis; Wireless Networks, Media Access Control, Multiple Access Control Protocols, and IEEE 802.11

DCF. The second part of the chapter discusses the related work of relevant studies and methods.

Chapter Three discusses the methodology of the proposed mechanism in this Thesis whereas Chapter Four evaluates the simulation results of the proposed CW mechanism compared to the simulation results of the CW mechanism used in BEB.

Finally; Chapter Five concludes the work of the thesis and highlights the future aspects to improve the suggested work.

CHAPTER TWO

LITRATURE REVIEW

This part of the thesis consists of three sections, the first two sections illustrate the background and knowledge related to the thesis's work and the last section discusses the related work and researches of some suggested CW control methods and modified BEB algorithms.

Wireless Networks can be classified according to their coverage range into the following types (Geier, 2004):

I. Wireless Personal Area Network (WPAN): a connection between two stations within a personal range (relatively very small area) such as Bluetooth and Infrared connections.

II. Wireless LAN: a connection between two or more stations within a local area coverage using the radio waves as medium.

III. Wireless Metropolitan Area Network (WMAN): the connection of more than one WLAN together.

IV. Wireless Wide Area Networks (WWAN): this type of wireless networks usually covers very large area such as a city or a group of cities.

This thesis focuses on WLAN's since it is the main area of the thesis's study and work.

2.1 WLAN's:

As defined earlier; WLAN's are the type of Wireless Networks that covers a local area such as home, office, school …etc. The stations in WLAN's refer to any device that can connect to the network; stations in WLAN's can either be mobile stations such as laptops or fixed stations such as desktops.

WLAN's have many unique characteristics over Ethernet or any other network types; such characteristics helped increasing the popularity of WLAN's over the years. The wireless nature of the network makes it more convenient as stations can connect to the network from any place within range without the need for cables which reduced the cost of network setup. The absence of wires allowed the stations to move within the wireless range of the network without being disconnected (Kurose and Ross, 2007). Another advantage for WLAN's is flexibility; WLAN's are easily expanded and new stations may join the network without any need of wiring and equipment's (Peterson and Davie, 2007).

2.1.1 WLAN's Architecture:

WLAN's can be structured in two different modes depending on the types of the contained stations (Geier, 2001). There can be two types of stations in WLAN's; Access Point (AP) and stations. In the infrastructure mode the WLAN contains an AP while in infrastructure-less mode (Ad Hoc mode) the WLAN does not contain an AP.

2.1.1.1 WALN Infrastructure mode:

Often referred to as Basic Service Set (BSS), WLAN stations are connected to a non mobile station called the AP with all communications between stations are done via the

AP. In order to be a part of the WLAN and be able to communicate the station must be in the transmission range of the AP which results a restriction over the mobility of the station since the AP is a non-mobile station. Figure 2 shows the infrastructure WLAN where the red circle indicating the range of AP.

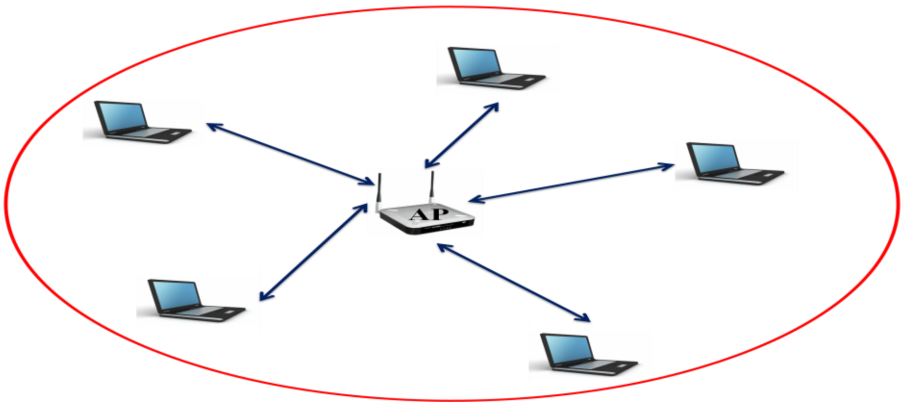

Figure 2: WLAN infrastructure mode.

2.1.1.2 WLAN Infrastructure-less mode:

Often referred to as Ad Hoc mode or Independent Basic Service Set (IBSS), in this mode stations can communicate directly without the need to AP. In this mode stations must be in range of each other in order to communicate. Figure 3 shows an infrastructure-less mode WLAN where each circle indicates the range of each station.

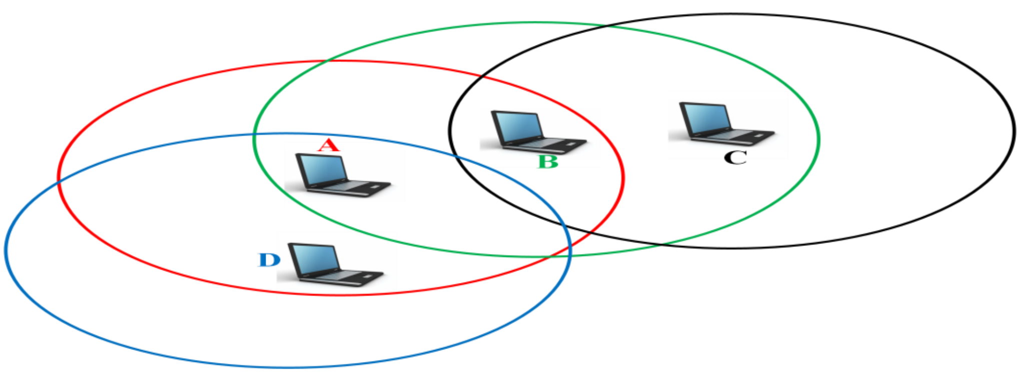

Figure 3: WLAN infrastructure-less mode.

An important feature of the infrastructure-less mode is that two stations can communicate with each other even if they were not directly in range (Multi Hop). For example in Figure 3 station D can communicate with station C through stations A and B which allows the WLAN to expand over a large distance. Another feature of the mode in discussion would be the low restrictions over stations mobility.

As stated in the previous chapter the MAC sub layer consists of two main functions to control the channel access; PCF controls the channel access in the infrastructure mode which implies a conflict free service where there are no chances for collisions to occur. In the infrastructure less mode where each station is independent and the chances of collisions are high; the channel access is controlled by DCF.

2.2 MAC Layer:

MAC is also referred to as Medium Access Control; MAC is a sub layer of the Data Link Layer and it is main responsibilities are to provide addressing and channel access control mechanisms which allow several stations to communicate using a common physical medium. Channel access mechanism is controlled by a MAC protocol known as Multiple Access Control Protocol which plays a crucial role in scheduling packet transmission fairly and efficiently among stations (Pan and Wu, 2008).

2.2.1 Multiple Access Control Protocols:

The Multiple Access Control Protocol regulates and controls the shared physical medium (channel) access by several stations; the main goal is to prevent, avoid or detect

collision and to utilize the channel access throughout the process. Many Multiple Access Control Protocols were suggested and used; these protocols employ different methods and strategies to regulate and control the channel access. Several classifications were suggested (Sachs, 1988) (Kurose, et al., 1988) (Rom and Sidi, 1990) (Kumar, et al., 2006); based on the previously mentioned classifications this thesis classifies the different Multiple Access Protocols as shown in Figure 4:

I. Conflict Free Protocols: designed to prevent collision by ensuring that a transmission when made will not be interfered or overlapped by another transmission therefore guaranteed to be successful. Such protocols can be further classified into two categories:

- Static Allocation Protocols: the channel access is divided among stations by means of time, frequency or channel division. Such protocols suffer a clear disadvantage which is providing channel access to stations that might not be interested in transmission.

- Dynamic Allocation Protocols: in such protocols the channel access is distributed among stations based on transmission request. These protocols aim to solve the disadvantage of static allocation protocols.

II. Random Access Protocols: in these protocols the channel can be accessed randomly; meaning that a transmission can be interfered or overlapped. Such protocols are designed to resolve such conflicts and guarantee that eventually all packets will be transmitted successfully. Such protocols can be further classified into two categories:

- Non Carrier Sense protocols: often referred to as slotted multiple access protocols, in such protocols the station which desires to transmit does not listen or sense the channel before starting the transmission.

- Carrier Sense Protocols: often referred to as probabilistic multiple access protocols. Such protocols imply that a transmitting station must sense if the channel is idle for a predetermined period of time before starting the transmission.

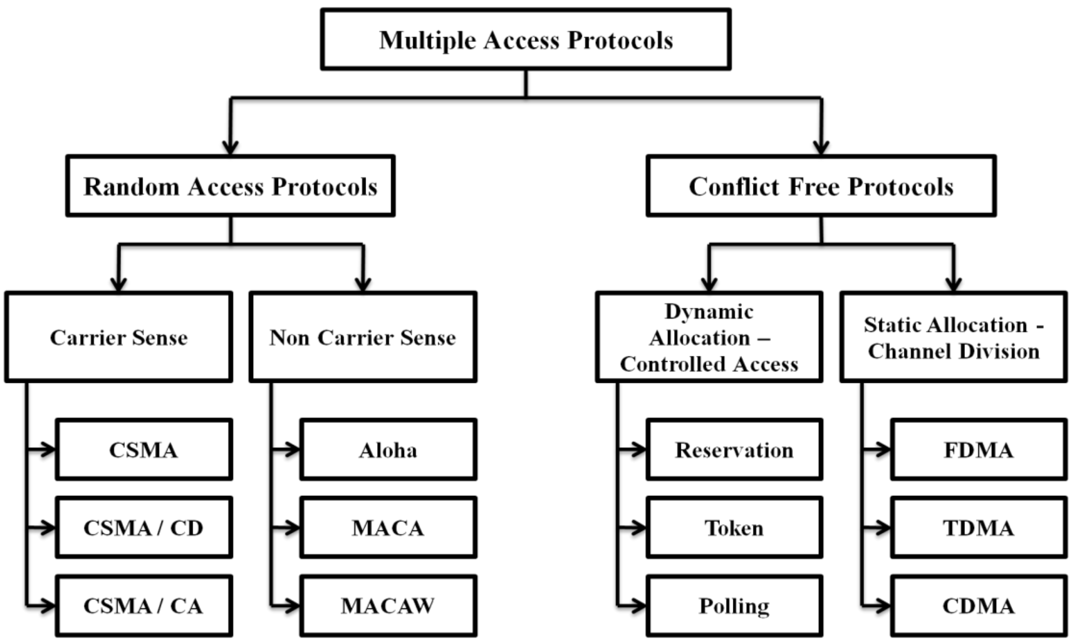

Figure 4: Classification of Multiple Access Protocols.

Random Access Protocols are often referred to as Contention Based Protocols (Goransson and Greenlaw, 2007) as they involve a competition to access the channel (only a single station is allowed to use the shared medium at a certain time). Allowing several stations to compete for the channel will cause a collision eventually; a collision is defined as a condition that occurs when two or more stations try to transmit over the same shared medium at the same time.

Multiple Access protocols are designed to handle collisions by preventing, detecting or avoiding them. Conflict free protocols are designed to prevent collisions by handing the channel access authority to the a central station which acts like a traffic controller deciding which station can access the channel and at the same time it prevents other stations from accessing the channel while it is busy.

Collision detection is achieved by sensing the channel after transmission to verify if a collision occurred; detection is achieved by capturing different data from the medium. Unlike the collision detection which acts after the collision has occurred collision avoidance tries to avoid collisions by sensing the channel prior to transmission and trying to find the appropriate time for transmission in order to avoid collisions. Both collision detection and avoidance are designed to handle collisions by employing a mechanism that reduces the probability of collisions reoccurrence.

The following subsections discuss the evolution of some Random Access Protocols until reaching the IEEE 802.11 standard Multiple Access Control Protocol.

2.2.1.1 Carrier Sense Multiple Access (CSMA):

It is a probabilistic Multiple Access Control protocol in which the station with a desire to transmit must verify if the channel is idle before staring the transmission, the channel is verified through carrier sense (Kleinrock and Tobagi, 1975).

Carrier Sense means that the transmitter senses the carrier (channel) before starting the transmission; if the channel is idle then it starts the transmission; if not then it keeps on

sensing the channel before trying to transmit again. Multiple Access describes how the physical media (channel) access is distributed among several stations.

The main setback of the CSMA is the hidden station problem (Tobagi and Kleinrock, 1975) which is illustrated in Figure 5; since stations A and C are not in the range of each other therefore are invisible to each other; station C will be unable to sense any transmission from station A. The problem occurs when station A is sending frames to station B and at the same time station C wants to send frames to stations B, in this case carrier sense is useless since C is unaware of A's presence and it will presume that the channel is idle.

The hidden station problem causes the performance of CSMA to drop sharply (Khurana, et al., 1998) since CSMA performance depends solely on the ability of stations to sense the channel before transmission. Another effect of the hidden station problem would be the delay caused by retransmission attempts due to collisions caused by the hidden stations.

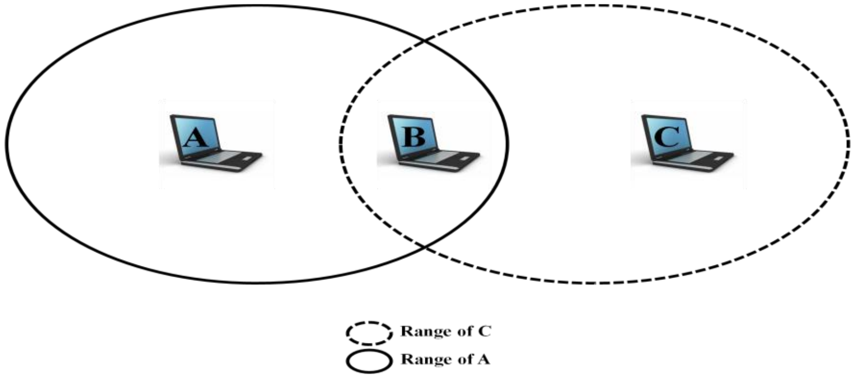

Figure 5: The Hidden Station Problem.

2.2.1.2 Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA):

CSMA lacks the ability to handle collisions, in Ethernet the CSMA was modified with a Collision Detection mechanism (CSMA/CD) to handle collisions, such mechanism will fail when used in wireless networks because of the following factors:

I. Collision detection is hard to be used in radio environment where the signal strength will decrease.

II. Some stations might be out of range therefore it will be impossible to detect their signals.

III. Stations from other networks may interfere.

These factors led to improving the CSMA with a Collision Avoidance (CSMA/CA) mechanism (Glass, et al., 1988). CSMA/CA implies that before starting the transmission the station must sense the channel for a predetermined time (less greedy than CSMA); if the channel is idle the station will start transmitting otherwise it will defer to a random period of time before transmitting again.

2.2.1.3 Multiple Access with Collision Avoidance (MACA):

MACA (Karn, 1990) is a slotted Multiple Access Control Protocol used to solve the hidden station problem by introducing the handshaking announcements; Request to Send (RTS) and Clear to Send (CTS). When stations in range of a sender or receiver hears the RTS or the CTS they will not try to transmit data for the period of time provided in the RTS or the CTS frames.

Other than solving the hidden station problem MACA provides the means of virtual sensing to detect collisions before starting the DATA transmission. Collisions occur only in RTS and are detected by the absence of CTS which means that collisions are detected on an instant using the RTS frame before the DATA is even sent; since RTS is shorter than the general DATA frame then the collisions duration will be reduced (Bianchi, 2000).

The process is illustrated in Figure 6, station A sends an RTS to station B which replies with a CTS message and station C though hidden to A will not try to access the channel after hearing the CTS frame from B. If another station tried to access the channel at the same time the collision will be detected since B will not reply with CTS thus the duration of collisions is reduced since collisions are detected as soon as they occur.

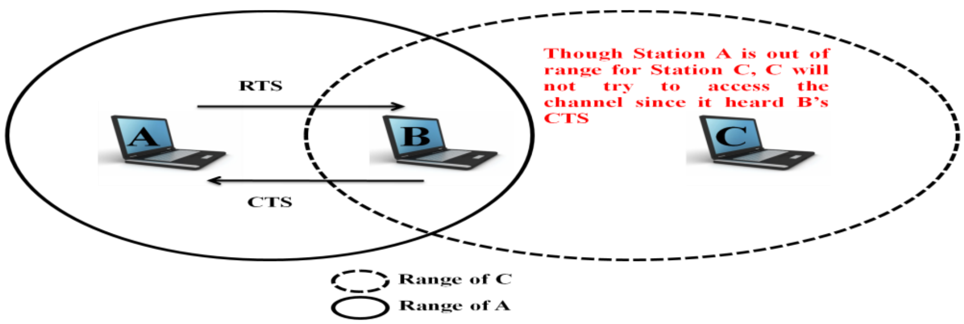

Figure 6: The RTS-CTS handshaking announcement in MACA.

2.2.1.4 Multiple Access with Collision Avoidance for Wireless (MACAW):

MACAW (Bharghavan, et al., 1994) is mainly an enhancement to MACA in order to increase the reliability by adding the Acknowledgment (ACK) and avoid unnecessary retransmissions. In addition to RTS and CTS exchanged by sender and receiver, the receiver will send an ACK after receiving the data. Given the fact that wireless media is unreliable compared to wire media the ACK frame will increase the reliability and reduce

the number of retransmissions. The optional RTS/CTS handshake in IEEE 802.11 DCF is adopted from MACAW protocol (Ye, et al., 2004) (Karl and Willig, 2005). Figure 7 illustrate how MACAW operates.

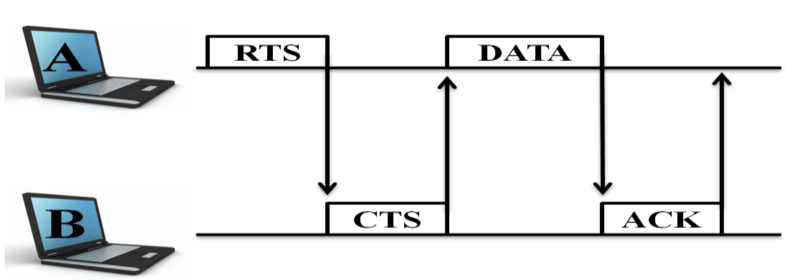

Figure 7: RTS-CTS-ACK in MACAW.

2.2.2 IEEE 802.11:

IEEE 802.11 is the set of standards for implementing WLAN computer communication (IEEE, 1999) and it covers both PHY and MAC layers. Due to its simplicity and effectiveness the standard has become widely accepted and implemented in wireless networks (Khalaj, et al., 2007).

As mentioned before the MAC sub layer consist of two main functions to define two different access methods for a shared medium; PCF and DCF, to add more flexibility both DCF and PCF can co-exist with each other and the two methods of channel access can alternate as needed (IEEE, 1999).

2.2.2.1 DCF:

DCF is defined as the fundamental and basic access method of the IEEE 802.11 MAC protocol (IEEE, 1999), it implies a CSMA/CA as the basic mode of channel access which

involves a DATA-ACK only. Another optional mode to access the channel involves exchanging four-way handshaking access method (RTS-CTS-DATA-ACK) combined with CSMA/CA (Chatzimisios et al., 2005 a) (Foh and Zukerman, 2002), the latter mode is used when the size of the frame to be sent exceeds a certain threshold (Chen and Li, 2004).

The channel access method operates as follow; a station with a desire to transmit must verify if the channel is idle by sensing the carrier for a predetermined period of time called Inter frame Space (IFS); the IFS designates the time interval between frames and its priority and length is determined by the type of frame the transmitter wishes to send. There are four IFS's implemented to provide priority levels:

I. Short IFS (SIFS): stations sending CTS, ACK or DATA frames will sense the channel for SIFS period of time. The SIFS is the shortest IFS which allow such stations to sense the channel for a lesser time than other stations hence accessing the channel before other stations. SIFS provides the priority to complete an existing transmission before starting a new transmission (Ho and Chen, 1996).

II. PCF IFS (PIFS): PIFS is longer than SIFS and is only used by the AP in PCF to send Beacon frame. AP has the priority to access the channel before any other transmitting station (incase DCF and PCF are working concurrently).

III. DCF IFS (DIFS): DIFS is longer than PIFS and it is used before sending an RTS.

IV. Extended IFS (EIFS): the longest IFS and it is used when an erroneous frame is detected.

SIFS has the highest priority of all IFS’s, the priority of SIFS allow an ongoing transmission to proceed without being interfered by a new transmission as shown in Figure 8. Stations A sent an RTS to station B, at the same exact time station C enters the range of A and B, unaware of any previous transmissions station C will sense the channel for a DIFS period of time which gives station B the chance to reply with a CTS before station C even finishes channel sensing, Upon hearing the CTS station C will recognize that the channel is busy.

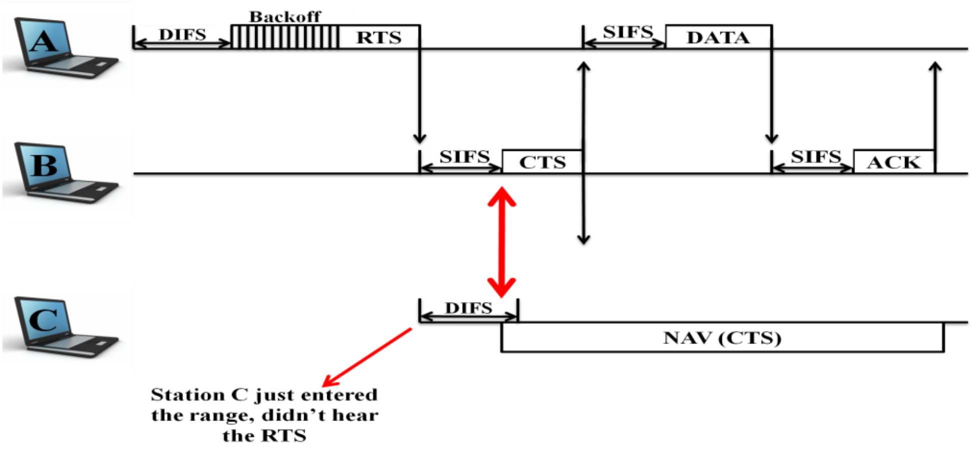

Figure 8: Priority of IFS.

After sensing if the channel is idle for the specified IFS interval the station is allowed to transmit the frames if the specified IFS is either SIFS or PIFS (if frames was CTS, DATA or ACK). If the specified IFS was DIFS (a station desires to initiate a transmission) the station must sense if the channel is idle for DIFS period of time plus an added random period of time equals to the value of the Backoff timer (Backoff will be further explained); if the channel were sensed to be busy during that time then the station must defer if not then the station is allowed to transmit.

In addition to the physical sensing the RTS-CTS-ACK provides a mean for virtual sensing. Since each frame contains information regarding the transmission duration then stations that heard RTS or CTS will update their Network Allocation Vector (NAV) with such values. The NAV is more like a counter that reflects that status of the channel; if the NAV value is zero then the channel is idle while a non zero value reflects an existing transmission. Figure 9 illustrates the DCF operation.

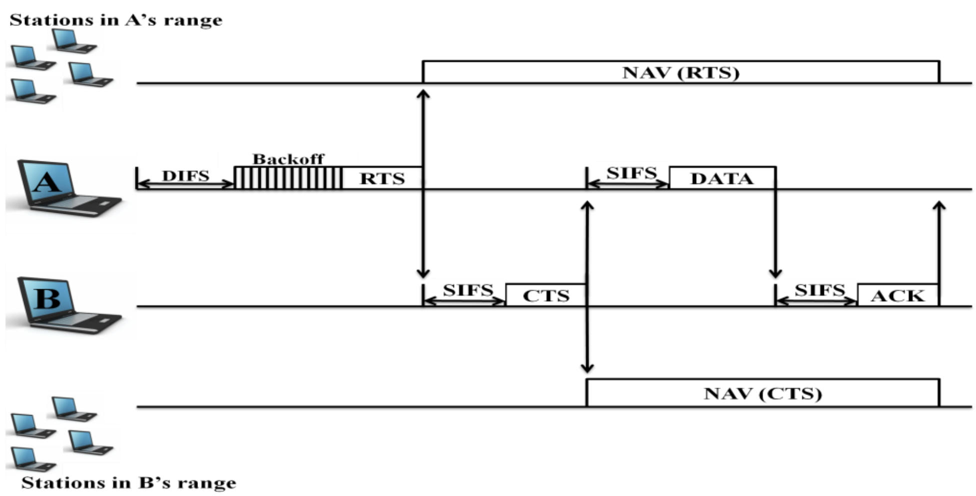

Figure 9: DCF Channel Access Mechanism.

2.2.2.2 Binary Exponential Backoff (BEB) Algorithm:

To reduce the probability of collisions (that occurs if two stations has the same backoff timer values) DCF employs a BEB procedure which operates as follows; after sensing the channel for a DIFS period of time the station starts a slotted backoff timer, the value of the timer for each station is picked randomly and depends on the size of Contention Window (CW) of that station as in Eq. 1:

$$\text{Backoff Timer} = \text{Random Number }]\, 0, CW+1] * \text{Slot Time} \quad (1)$$

The station keeps on sensing the channel for the period of the backoff timer, at each time slot the channel is sensed; if the channel was idle then the backoff timer is reduced by a slot time otherwise it is paused (the backoff timer will be resumed once the channel is idle again). When the station's backoff timer reach the value zero that station is allowed to transmit; this allows the station with the lowest backoff timer to access the channel before other stations hence will reduce the probability of a collision since the values of the backoff timer for each station is chosen independently and randomly.

If two stations had the same values for backoff timers (picked the same random number) a collision will occur; in this case the value of CW will be doubled and the backoff timer is recalculated again using the new CW and the process is repeated. At each failed transmission the value of CW is doubled until it reaches the CW maximum (CWmax), in 802.11 BEB the CWmax equals 1023. If transmission was successful (ACK received) then the sender's CW value will be reset to CW minimum (CWmin) in 802.11 BEB the CWmin value equals 31. Figure 10 shows the exponential increase of CW.

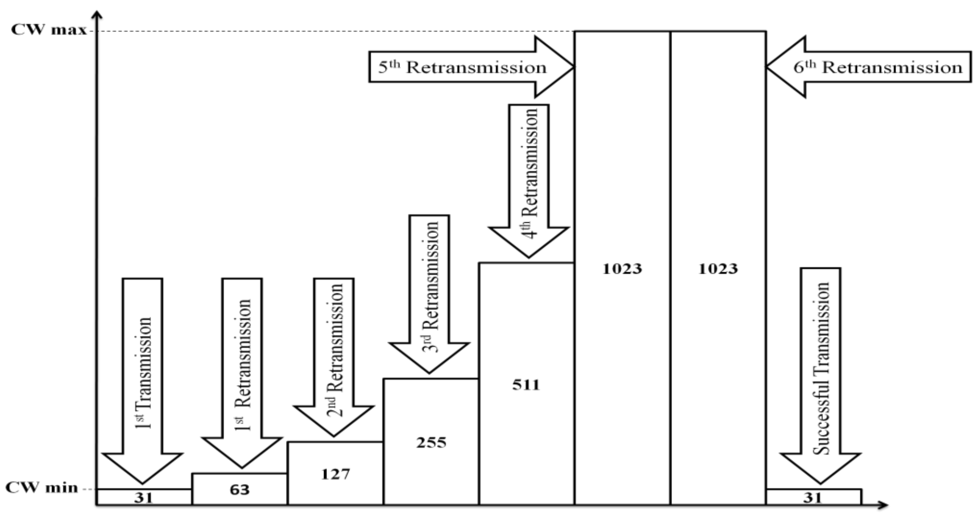

Figure 10: The Exponential increase of CW.

BEB is often referred to as the Truncated BEB (Manaseer, 2009) because after a certain retransmissions (when the size of CW reaches the CWmax) the exponential increase of CW so the maximum delay will be 1023 (the value of CWmax).

The collision resolution process is illustrated in Figure 11; both stations A and B are trying to access the channel, after sensing the channel for a DIFS period of time both stations randomly generate a number and update their corresponding backoff timer, in this case both A and B have chosen the same random number which means both stations will access the channel at the same time which will result a collision. The Collision is detected by the absence of CTS frame so upon detecting the collision both stations will defer, exponentially increase the CW and enter the competition again. In the first retransmission attempt A will wait less than B therefore will access the channel first, the RTS sent by A will be heard by B, upon hearing the RTS station B will pause it backoff timer for the transmission duration.

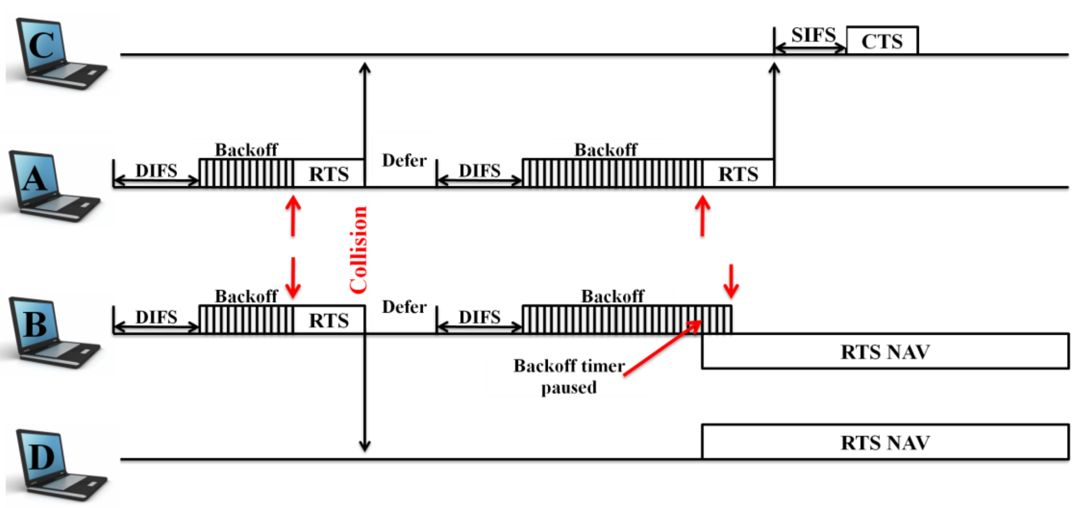

Figure 11: Collision Resolution in DCF.

BEB suffers three major problems concerning the CW adjustment mechanism; these problems would affect the performance of the DCF. This thesis suggests that any efficient modification to the BEB should address these following problems in order to improve the performance of DCF:

I. Problem 1: starting with the CWmin would result a certain collision if the number of competing stations are higher or equal to the CWmin value.

II. Problem 2: increasing the CW exponentially would result a huge delay especially when the number of stations is high.

III. Problem 3: setting the CW to CWmin after a successful transmission would favor winning stations and newly competing stations and give them a clear advantage over other stations regarding channel access chance (Manaseer, 2009).

The first two problems will cause deficient use of the channel whereas the third problem will reduce fairness among stations regarding channel access. Due to the previously mentioned problems the CW control in BEB was the topic of many researches, the next section discusses several suggested method concerning the CW control.

2.3 Related work:

The BEB was implemented to reduce the probability of collisions and provide a fair channel access chance to competing stations. The problems mentioned in the previous section reduce the performance of the IEEE 802.11 DCF and triggered the need for a better CW control method to achieve better performance.

Modifying the CW control mechanism in BEB or suggesting a new Backoff algorithm is one of the most researched topics in the area of wireless networks, most suggested CW control mechanisms falls within two main categories (Manaseer, 2009) (Balador, et al., 2010)**:**

I. Static modifications: controlling the CW based on a static scale, suggestion aimed to modify the CW increment/decrement method. Such mechanisms are easy to implement and do not involve gathering data but still they will suffer the same limitations as BEB.

II. Dynamic modifications: the CW control is affected by many factors such as number of active stations, the channel status and error rate, by taking such factors into consideration these methods will avoid the BEB limitations but still they require gathering data before adjusting the CW.

The CW related research approaches tended to address the major problems of the BEB algorithm concerning the CW control, one of the approaches addressed the fairness problem which was caused by the sudden decrease of CW to CWmin while other approaches addressed the delay problem caused by the exponential increase of CW.

The authors of (Ni et al., 2003) suggested that a successful transmission would result a convenient size of the CW and recommended that slow decrease of the CW after a successful transmission would improve the performance. The suggestion changed the direction of CW research from how to increment the CW into how to decrement the CW, though the suggestion maybe true and attractive it fails to notice that no matter what is the

size of the CW the value of backoff timer is picked randomly. The range of CW only aims to reduce the probability of the collision and can give a false indication regarding the convenient size of the CW. In Figure 12 both stations A and B desire to transmit, randomly both stations pick the same value to update their corresponding backoff timer which results a collision; both stations increase the CW size exponentially and retransmit again, according to (Ni et al., 2003) the updated CW size (CW = 63) should reflect the convenient CW size though it clearly doesn't; only two stations are competing for the channel and it is obvious that the two stations can even pick numbers from a lesser range and still not suffer a collision which means that the whole process is controlled by a probability and randomness more than anything else.

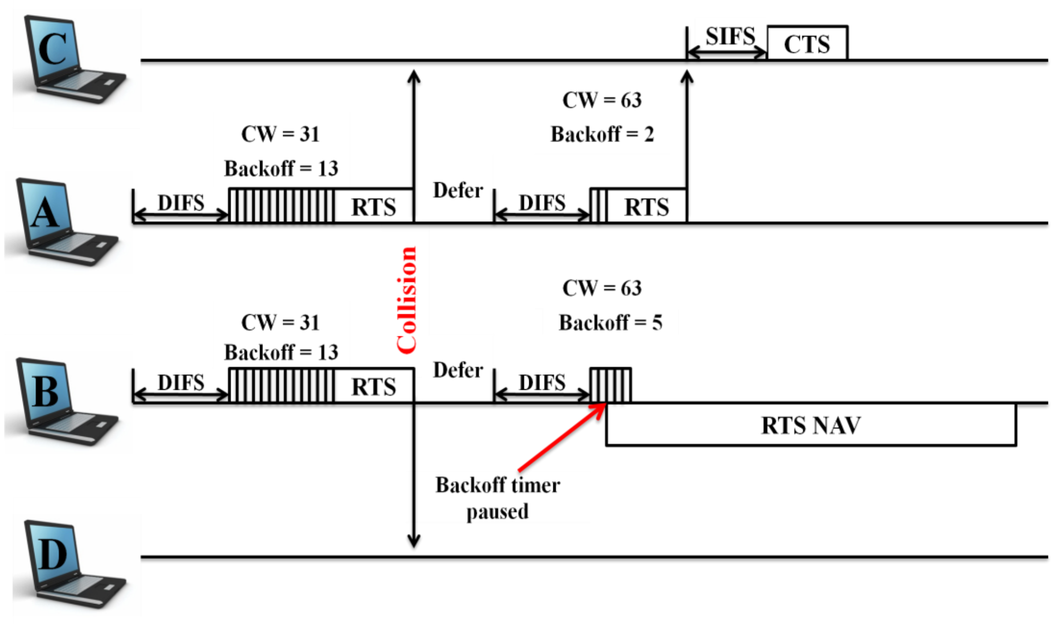

Figure 12: Probability and Randomness in CW.

The authors of (Bharghavan, et al., 1994) suggested a Multiple Increment, Linear Decrement (MILD), this method suggests increasing the CW size by a factor (1.5)

instead of doubling it in case of a collision, it also suggest decreasing the CW by a linear function if the transmission was successful. The suggested modifications increases the size of CW slower than 802.11 BEB method in case of a collision and slowly reduce it after a successful transmission, though these modifications will reduce the delay and achieve fairness the suggested method will suffer in lightly loaded network since it requires a long time to reach the initial CWmin.

Several researches suggested a Double Increment, Double Decrement (DILD) CW control (Natkaniec and Pach, 2000) (Moura and Marinheiro, 2005) (Chatzimisios et al., 2005 b), those methods suggested doubling the size of CW in case of a collision and decrease the CW size by a double when transmission is successful (instead of resetting the CW to CWmin), though this method tries to achieve fairness by decreasing the CW size gradually it never addressed the problems of the initial CW size and the exponential increase of CW.

Another suggested CW control mechanism is the Exponential Increment, Exponential Decrement (EIED) (Song et al., 2003) (Song et al., 2005), EIED introduces two new variables called increment variable (r_i) and decrement variable (r_d) , the CW size will be multiplies by the increment factor in case of a collision and multiplied by the decrement factor when the transmission is successful when transmission is successful, both variables are obtained by experiment, EIED is mainly an improvement to MILD, in order for the EIED to perform efficiently the values of both factors (r_i and r_d) must be calculated to represent the current status of the network which is hard and requires computation time,

EIED can be enhanced by introducing different values of both factors to be used based on the channel status.

The previously suggested methods fall under the Static CW adjustment category, such methods employ a static increase or decrease on the CW without taking into consideration the conditions of the network, another limitation of such methods is addressing the fairness problem in BEB only without paying any attention to the other problems in BEB.

Another trend of CW control research was the Dynamic CW modification; suggested methods took into consideration several factors affecting the CW control such as network condition, number of active stations, channel status, history of transmission and the total number of stations.

The CW control suggested in (Cali, et al., 2000) presents an adaptive CW decrease that takes into consideration the network conditions, this method presents a computational method to calculate the CW based on the current status of the network; though such computations may result a convenient CW size the computations required in this method are complicated and requires time.

The Neighborhood Backoff Algorithm (Taifour, et al., 2005) suggests taking into consideration the total number of stations in the network when adjusting the CW, though taking the total number of stations into consideration might provide a better adjustment of the CW the suggested method ignores the fact that some station might be active and competing for the channel while others are inactive, another setback of this method is the

nature of wireless network implies that the total number of station will change since station can leave and join the network on regular basis.

The authors of (Ksentini et al., 2005) suggested a Determinist Contention Window Algorithm (DCWA), DCWA Divides the CW into ranges and instead of just doubling the CW size by doubling its upper bound, DCWA increases both upper bound and lower bound, it also takes into consideration the network load and history before readjusting the CW size, the main setback of the suggested method is the fairness problem since stations will be categorized into ranges, different ranges will have different chances accessing the channel.

The authors of (Romaszko and Blondia, 2006) suggested a Dynamic Distributed CW Control, the suggested method pays more attention into probability by relating the lower CW bound and the upper CW bound to the number of neighbors and number of failed retransmission attempts, it introduces 3 algorithms to adjust the lower bound and the upper bound of CW, this method tries to solve the problems in BEB but using this method requires computations which will increase the delay.

An Adaptive Contention Window Scheme (ACW) was suggested by the authors of (Elhag and Othman, 2007)**,** this scheme takes into consideration the number of active stations when adjusting the CW initial size and also CW maximum size though these factors help in avoiding collisions the nature of wireless network makes it hard to figure the number of stations competing for the channel since new stations might just join the

network besides it reflects the most previous network condition rather than the current network condition.

The authors of (Kumar, et al., 2006) suggested a mechanism to modify the CW size by taking into consideration the number of predicted active stations by observing the current channel status; this method requires complex computations to predict the number of active stations which will increase the delay, another setback would be that predicting the number of active stations is impossible in wireless networks.

The History Based CW Control (HBCWC) was suggested by the authors of (Balador et al., 2010 b), this method introduces a Channel Status (CS) array in addition to two variables (x and y) to control the size of CW based on the history of the latest three transmission attempts, the suggested method also tries to distinguish the packets lost due to collision from packets lost due to error based on the idea that collisions may only occur in RTS, the CS array holds values that represent the transmission history, CW will be adjusted according to the entries in the CS array, the main setback of this technique is the time required to update and check the CS array by each station, another limitation would be increasing the CW to the maximum when the values of CS array reflects consecutive transmission failure which will cause the same fairness problem in BEB.

To overcome the fairness problem in HBCWC the authors of (Balador et al., 2010 a) suggested a modified adaptive history based CW control (AHBCWC) to overcome the fairness problem the modified method suggested decreasing the CW to CWmin when the CS array reflects consecutive failure transmissions, this led to another limitation, failure

transmission are caused mainly by collisions which indicates that many stations are trying to access the channel; setting the CW to CWmin would only increase the chances of collision.

Chapter Three

Methodology

The current channel access mechanism in 802.11 BEB operates in a very simple and effective way as shown in Figure 13. The previous chapter illustrated the main problems in the current channel access mechanism; this chapter introduces a theoretical analysis of the proposed CW mechanism, its variables and how it operates.

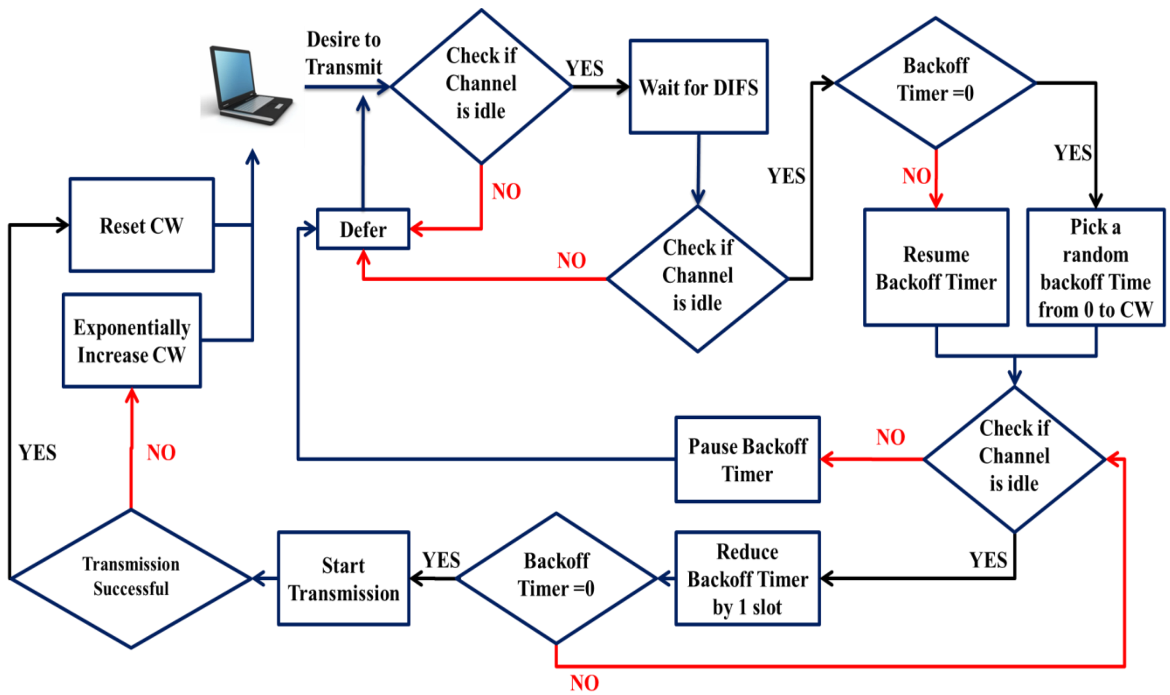

Figure 13: Channel Access method in BEB.

As discussed earlier Most suggested CW control mechanisms follow two main approaches (dynamic or static) to solve the current problems in BEB. This thesis propose a modified CW mechanism that follows a different direction, the proposed mechanism is

more interested in solving collisions once they occur rather than reducing the probabilities of collisions reoccurrences. The next section discusses the proposed CW mechanism

3.1 The modified CW Mechanism:

The suggested CW mechanism solves the problems of CW mechanism used in BEB in order to achieve a better performance and channel utilization. To solve the fairness problem the suggested mechanism implies a fixed CW size on all stations which provides an equal channel access opportunity for all stations regardless of successful or failure transmissions.

In addition to solving the fairness problem the suggested mechanism aims to reduce the delay by solving the collisions rather than increasing the CW size; in BEB the CW size is increased to reduce the probability of collisions in the first retransmission. Though such increase effectively reduces the collision probability it still increases the delay especially when taking into consideration that the CW size can still increase due to packet lost rather than collision.

Finally the number of active stations can increase collisions when the CW is initiated to CWmin; the modified mechanism solves the problem by initiating the CW size to CWmax.

3.1.1 Modified CW mechanism's Variables:

In order for the suggested mechanism to operate it uses the following variables to update the value of the backoff timer:

I. CW: discussed in the previous chapters however in the proposed mechanism the CW value is fixed and always equal to CWmax.

II. CW1: an integer value randomly picked from the range]0, CW+1].

III. Retransmission Factor (RF): an integer equal to either 32 (CWmin) or 64 (2 * CWmin); its value depends on the number of retransmissions; in the 1st transmission and retransmission RF = 32, in the 2nd and 3rd retransmission RF=64.

IV. Collision Inter Frame Spacing (CIFS): CIFS is introduced to solve the collision in the first retransmission; CIFS is assigned the highest priority and its one slot less than SIFS.

3.1.1.1 CW:

A static value equals to CWmax, the modified mechanism does not involve CW increment or decrement at all; since all stations have the same CW value then all stations have an equal opportunity to access the channel.

3.1.1.2 CW1:

The value of CW1 is an integer value picked from the range]0, CW+1] and will be used to update the backoff timer, the value of CW1 is updated after a successful transmission or when the packet is dropped upon reaching the maximum retransmission retry limit.

3.1.1.3 RF:

The value of RF will be used to update the backoff timer along with CW1; it depends on the number of retransmissions. The RF value is initialized to 32 or CWmin, in case of collision (1st retransmission) the RF value will not be changed, if a collision still occurs the value of RF will be doubled to 64. Same as CW1 the value of RF will be reset to 32 in case of successful transmission or upon reaching the maximum retransmission retry limit. The process of updating the backoff timer using CW1 and RF is shown in Figure 14.

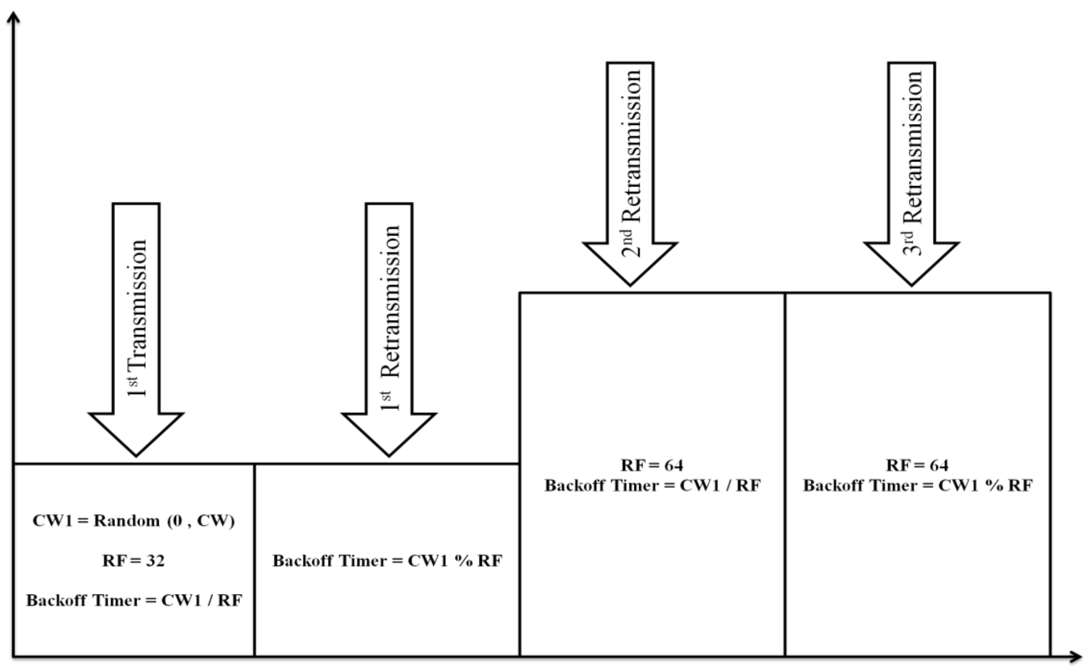

Figure 14: Calculating the backoff timer using CW1 and RF.

3.1.1.4 CIFS:

CIFS value will be one slot less than SIFS; it is used to provide priority for the retransmission over any other transmission. Providing CIFS the priority over SIFS will not violate the priority rules of the different IFS's since CIFS will only take advantage of such

priority over DIFS only; in other words CIFS is used only in case of collisions which indicates the absence of SIFS since the collided stations have already sensed the channel for DIFS period of time.

3.1.2 The Modified CW Mechanism Operation:

The modified mechanism recognizes that the whole process of CW adjustment is controlled by probability and randomness more than anything else. No matter how many calculations performed or factors taken into consideration collisions will still occur; so rather than just trying to reduce the collisions probabilities the modified mechanism aims to solve collisions when they take places.

The modified mechanism operation is illustrated in Figure 15. If a station desires to transmit it must verify if the channel is idle, if so the station will update the backoff timer using the values of CW1 and RF, to reduce the delay the value of CW1 is divided by the value of RF so the maximum delay will be 32 slots at maximum. If a collision occurs the backoff timer value will be updated to be (CW1 % RF); to avoid any conflicts with other transmissions the retransmission attempt will sense the channel for CIFS period of time instead of DIFS therefore collided stations will access the channel before any other stations.

In the proposed mechanism for a collision to reoccur in the 1st retransmission then two stations must pick the same random number of the range]0, 1024] while in the 802.11 BEB a collision will reoccur in the 1st retransmission if two stations picked the same random number from the range]0, 64], it is obvious that the probabilities of a collision to

reoccur are extremely lower when using the proposed mechanism compared to the 802.11 BEB.

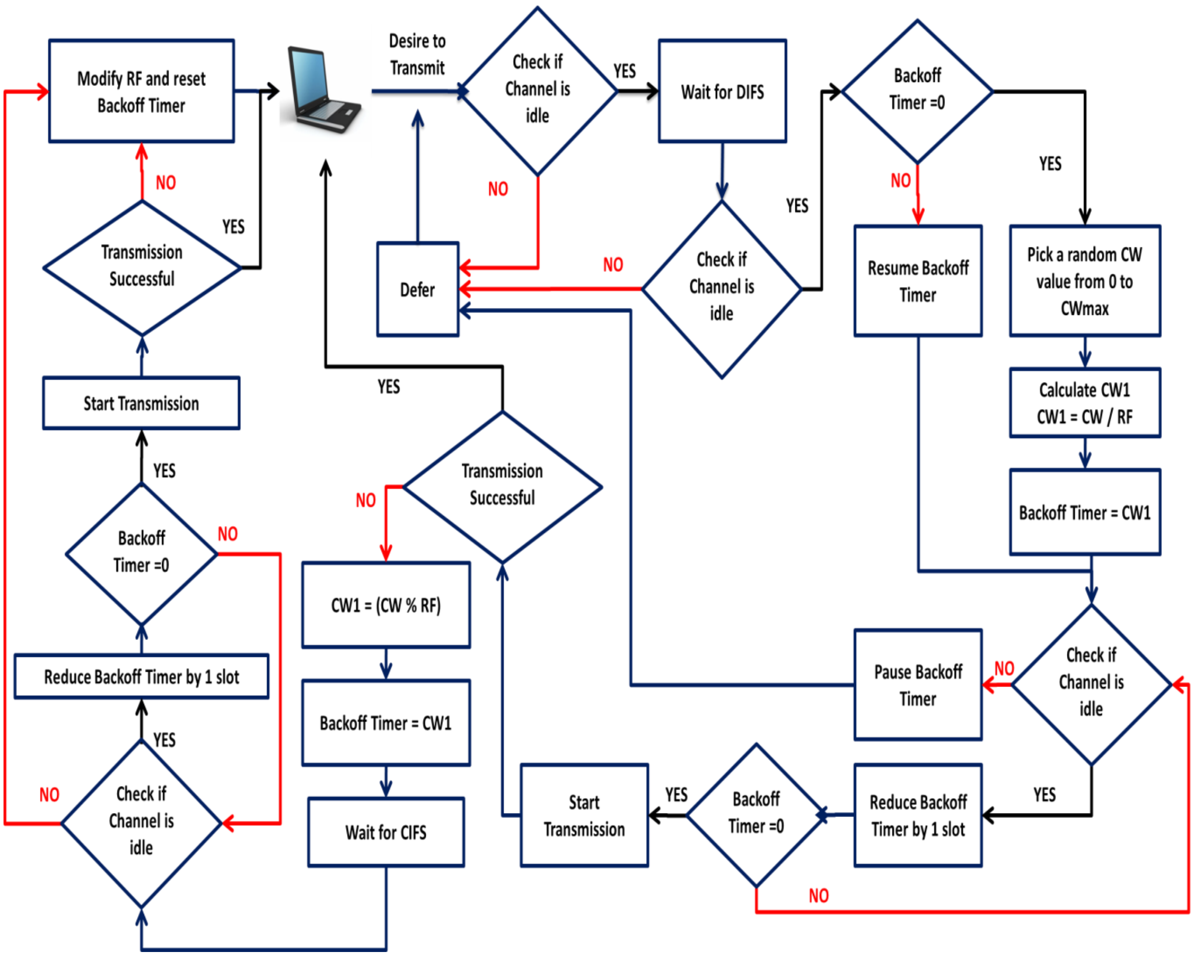

Figure 15: Channel Access in the modified CW mechanism.

The process of collision resolution is illustrated in Figure 16; both stations A and B try to access the channel and both picked random number CW1, the backoff timer is updated with the corresponding value of (CW1 / RF), if a collision occurs then both stations defer and update the value of the backoff timer, instead of doubling the CW size the modified mechanism distinguish both stations' backoff by using the formula (CW1 mod RF) which

lower the probability of a collision greatly, a collision at retransmission will only occur if both stations picked the same value of CW1; furthermore the delay is reduced since the CW is not increased due to collisions.

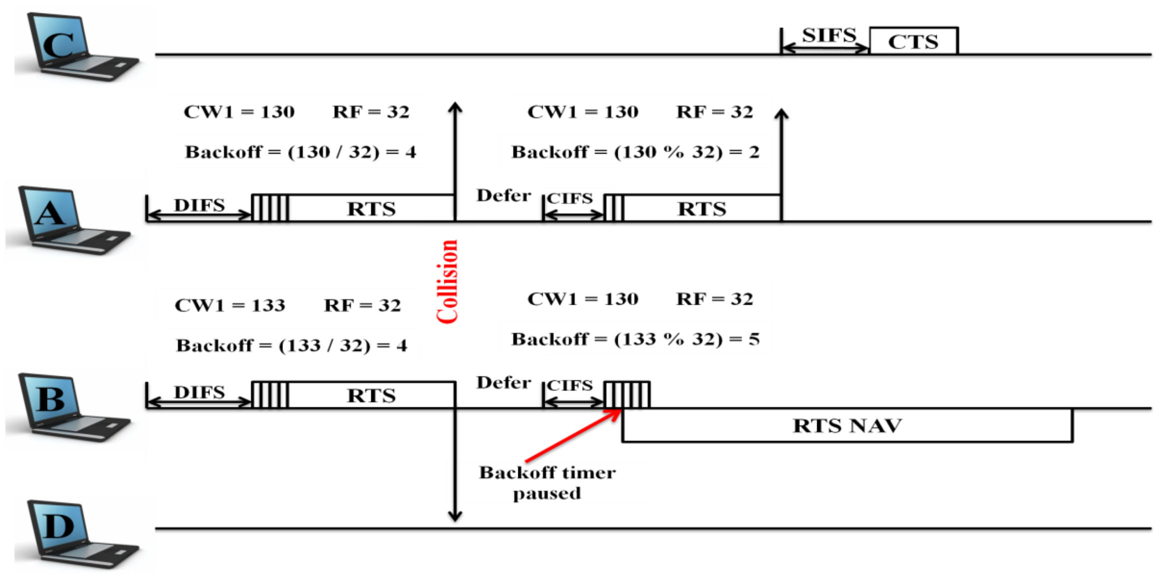

Figure 16: Collision Resolution in the modified CW mechanism.

The priority of CIFS over DIFS plays an essential role in the modified CW mechanism, the role is explained further in Figure 17; a collision resolution between stations A and B, station A will retransmit even if station D is trying to resume its backoff timer since station A will sense the channel for a lesser time than station D.

CIFS provided priority for the retransmission over any transmission therefore played a significant role in the collision resolution process, if station A had to wait for DIFS period of time then station D will access the channel before and the whole collision resolution process will be deemed useless.

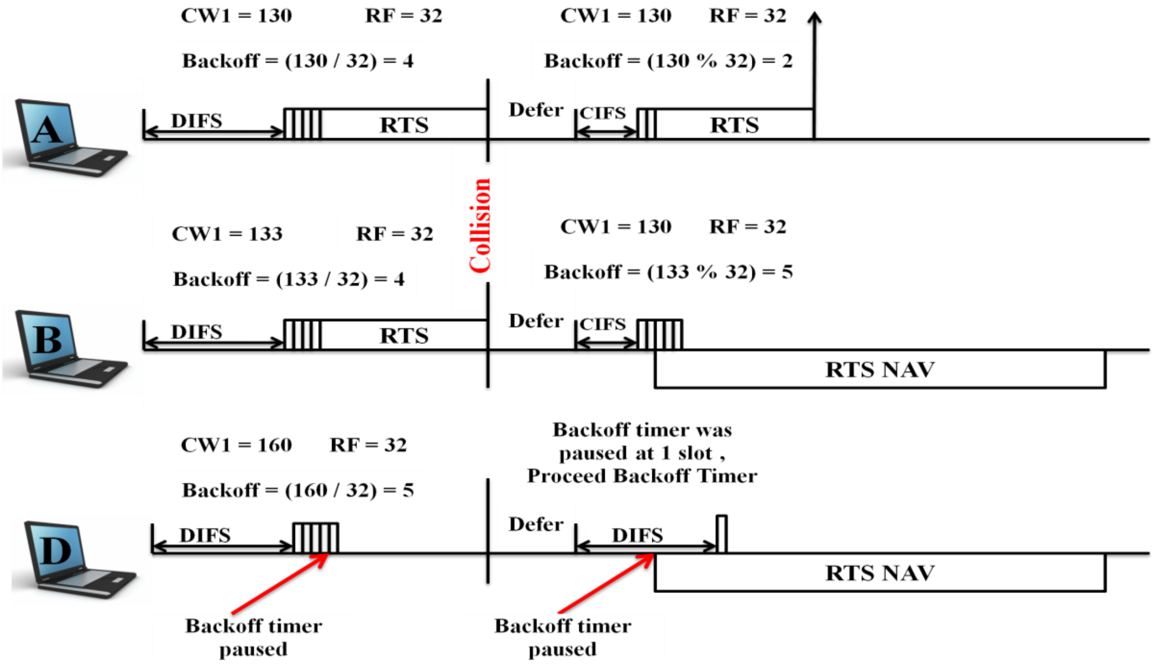

Figure 17: The role of CIFS in collision resolution process.

CHAPTER FOUR

SIMULATION & RESULTS EVALUATION

To evaluate the performance of the proposed CW control mechanism in various network conditions various scenarios were implemented using the QualNet simulator 5.0; QualNet simulator is specialized in simulating Wireless applications and it runs on most common software; it is easier to install and use than other network simulators. The main advantage of QualNet is its speed in running complex scenarios. Other advantages of QualNet over other simulators are:

I. Easy-to-use and clear Graphical User Interface (GUI).

II. Wide range of possible applications especially for wireless applications.

III. Support for multiprocessor systems and distributed computing.

IV. Sophisticated animation capabilities.

V. Extensive possibilities for analyzing scenario.

VI. The wide range of documentation from the user guide to the programmers guide.

4.1 Implementing the Modified Mechanism in QualNet:

To implement the proposed mechanism in QualNet the files `mac802_11sta.cpp` and `mac802.11sta.h` were modified; the modifications involved the functions; mac dot 11 station set backoff if zero, mac dot 11 station reset cw and mac dot 11 station increase

cw; furthermore the variables CW1, RF and CIFS were defined and introduced. The modified files are located in the wireless library of QualNet; after modifying the files QualNet must be compiled before being used. Different simulation scenarios were designed and tested on both the 802.11 CW control mechanism and the modified CW mechanism.

4.2 Simulation Scenarios:

Two network scenarios were used to measure the performance of the proposed mechanism versus the current mechanism used in 802.11 BEB, each scenario were repeated three times; at each time increasing the number of packets to be sent per transmitter station from 10 packets to 100 and finally to 1000 packets. Each scenario is tested at various packet rates Packets per second (PPS); while the packet rate reflects the network load (as the packet rate increases the network load increases) the number of packets to be sent reflects that loads duration, various packet rates were used starting from 6, 10, 20, 50, 100, 140 and 200 PPS. The scenarios were designed as follows:

I. Scenario One: 20 stations where 18 stations are transmitting and 5 stations are receiving, the scenario design contains 4 groups of stations, each group contains 5 stations, in each group 4 stations are sending data to 1 station (16 data transmissions) and the other two data transmissions will be between the most distant receiver stations (centers of the 4 groups).

II. Scenario Two: 50 stations where 44 stations are transmitting and 14 stations are receiving; same as the previous scenario but the number of groups here is increased

to 10 rather than 4. The scenarios design aimed to increase the number of collision in order to evaluate the performance of both mechanisms under study.

4.3 Simulation Parameters:

The number of stations was respectively 20 and 50 stations as discussed earlier, for each scenario the number of packets to be sent by each transmitting station is 10, 100 and 100 respectively; each transmitter will send these packets at various packet rates staring from 6, 10, 20, 50, 100, 140 until reaching 200 PPS.

Other simulation parameters were fixed for both scenarios including the simulation time, the area, packet size, the traffic type and transmission range, Table 1 shows the values of these common parameters.

Table 1: The values of the common simulation parameters

Parameter	Value
Simulation Time	1000 Seconds
Area	1000 x 1000 m^2
Packet Size	512 Bytes
Traffic Type	Constant bit rate (CBR)
Transmission Range	250 m

The simulation time value depends on the scenario itself and it affects the result of the simulation. Experiments in (Manaseer, 2009) showed that the simulation time should be greater than 800 seconds to allow the network to stabilize; in this simulation both 800 and 900 seconds were not enough to completely run the scenarios therefore the simulation time is set to 1000 seconds.

The maximum packet size in 802.11 is 2346 bytes; while larger packet size can reduce the network overhead; smaller packet size will reduce errors in packets (Yin, et al., 2004). In this simulation the packet size were chosen to be 512 bytes to reduce the number of packet errors, in this simulation the number of packets sent is far more important than their corresponding size that's why it was more convenient to use smaller packet's size. The traffic type is set to CBR to avoid any variations between different scenarios, finally Table 2 shows the hardware and software specifications used to implement the simulation.

Table 2: Specifications of the Hardware and Software used in Simulation.

Parameter	Value
Processor	Intel Core 2 Duo 2.00 GHz
Random Access Memory (RAM)	3 GB
Operating System (OS)	Windows XP
OS Type	32-bit

4.4 Performance Metrics:

Several performance metrics can be chosen depending on the aims of the simulation; the following metrics are used to evaluate the performance of the proposed mechanism versus the current CW mechanism used in 802.11 BEB. Since QualNet produces the statistics of simulation per station (Zhou, 2006) an average or summation of the results are used to evaluate the performance:

I. Average Jitter: Jitter delay is the variation in the delay between packets; jitter delay can be caused by the packet position in the queue or by bandwidth congestion (Raptis et al., 2007) (Xie et al., 2009). Jitter delays affect the performance of the network and the data quality; the aim is to reduce the jitter delays and hopefully reach the value of zero, jitters are measured in seconds.

II. Average end to end delay: it is the total time needed by the packet to travel from the transmitter to receiver; the aim is to reduce the delay as possible, measured in seconds.

III. Packets dropped due to transmission limit: BEB employs restrictions over the number of retransmissions allowed for each packet depending on the packet size; short packets retry limit is 7 retries and long packets retry limits is 4; this performance metric was picked mainly to explain the throughput results since the retry limits allows the current CW mechanism to perform efficiently by avoiding large exponential increase in CW size.

IV. Packet Delivery Ratio (PDR): the ratio of the number of packets received to the total number of packets sent; a higher PDR reflects a better network performance.

V. Throughput: the number of packets successfully received in a period of time; measured by kilo bytes per second (Kbps), it is the same as PDR but here measured in Kbps instead of ratio.

4.5 Simulation Results:

4.5.1 Average Jitter:

The statistics output file in QualNet calculates the average jitter for each receiving station so in order to compare the results for both the 802.11 BEB and the Modified CW mechanism, the average jitter of all receiver stations is calculated. Each scenario is tested 18 times; each time adjusting the total number of packets to be sent by each transmitter station to 10, 100 and 1000 packets described as test 1, test 2 and test 3 respectively for 6 different packet rates, Figures 18 - 23 represent the average jitter of both methods:

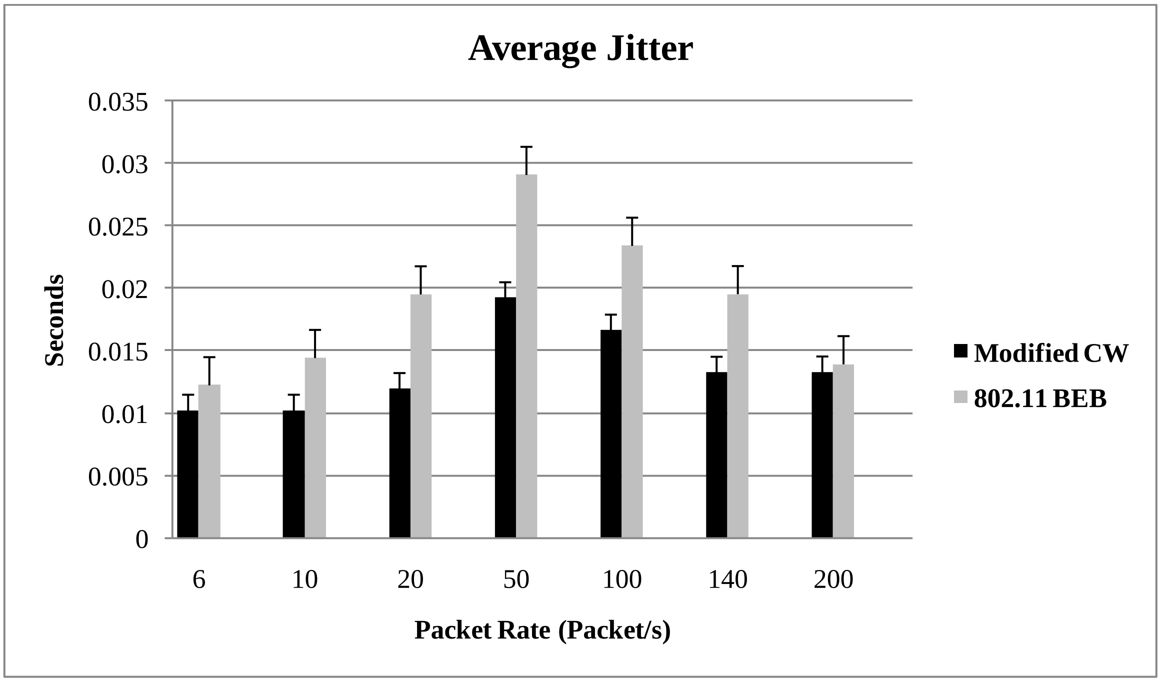

Figure 18: Average Jitter of 802.11 BEB and Modified CW for scenario one – test1.

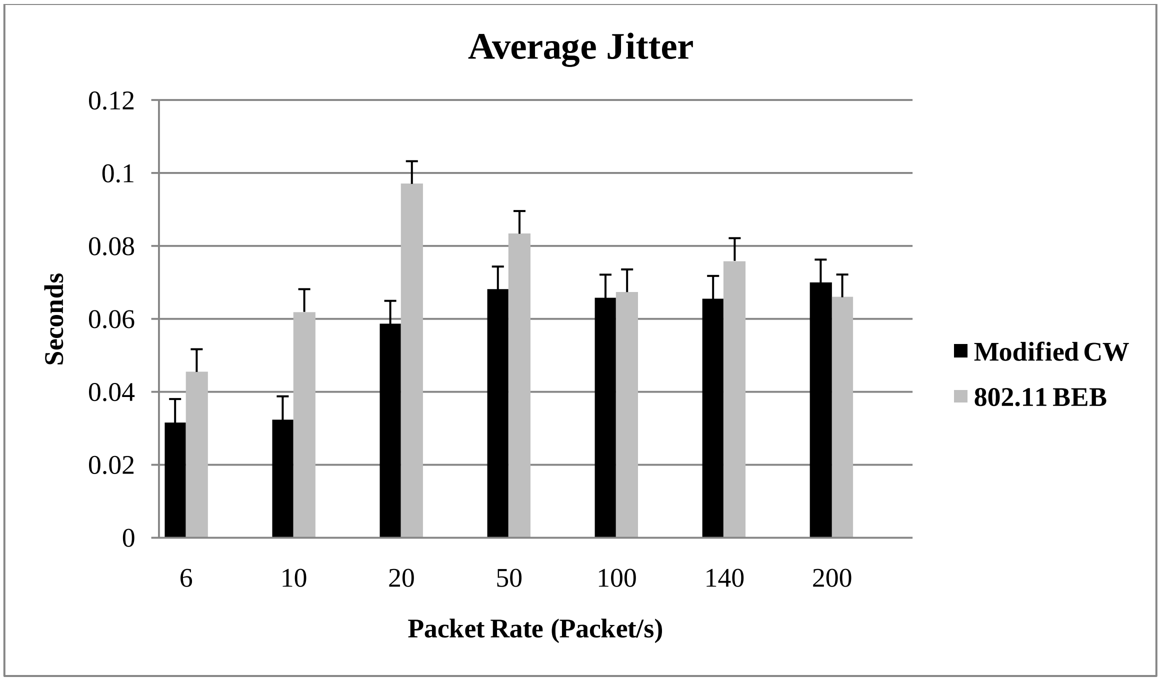

Figure 19: Average Jitter of 802.11 BEB and Modified CW for scenario one – test2.

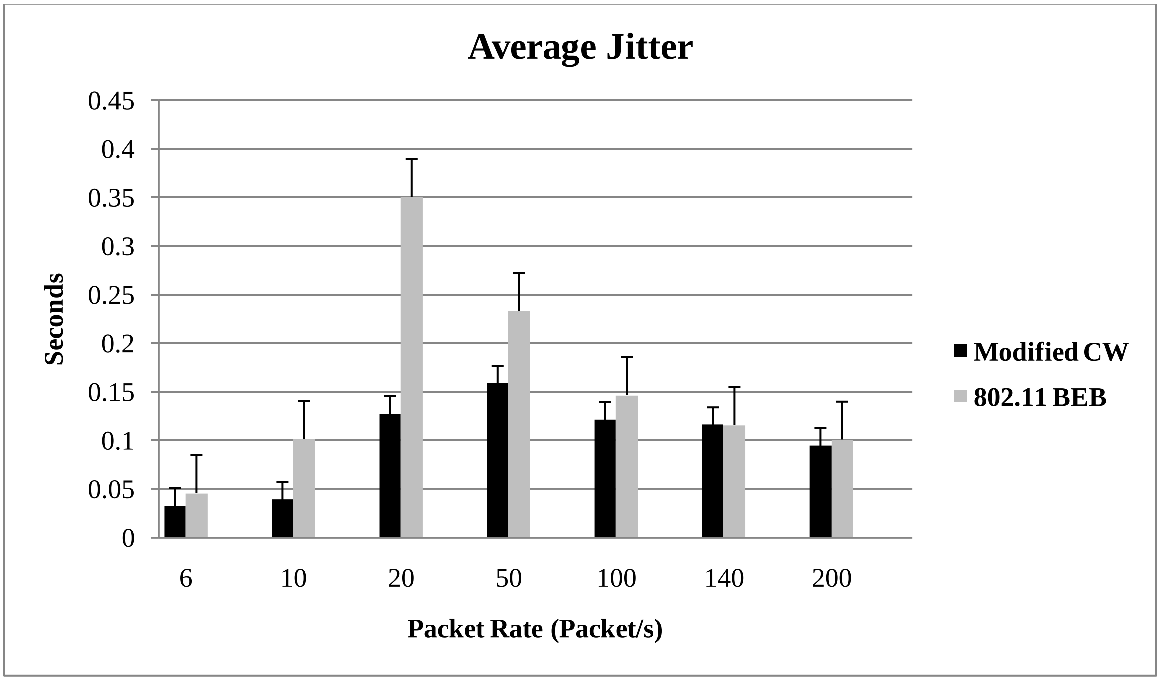

Figure 20: Average Jitter of 802.11 BEB and Modified CW for scenario one – test3.

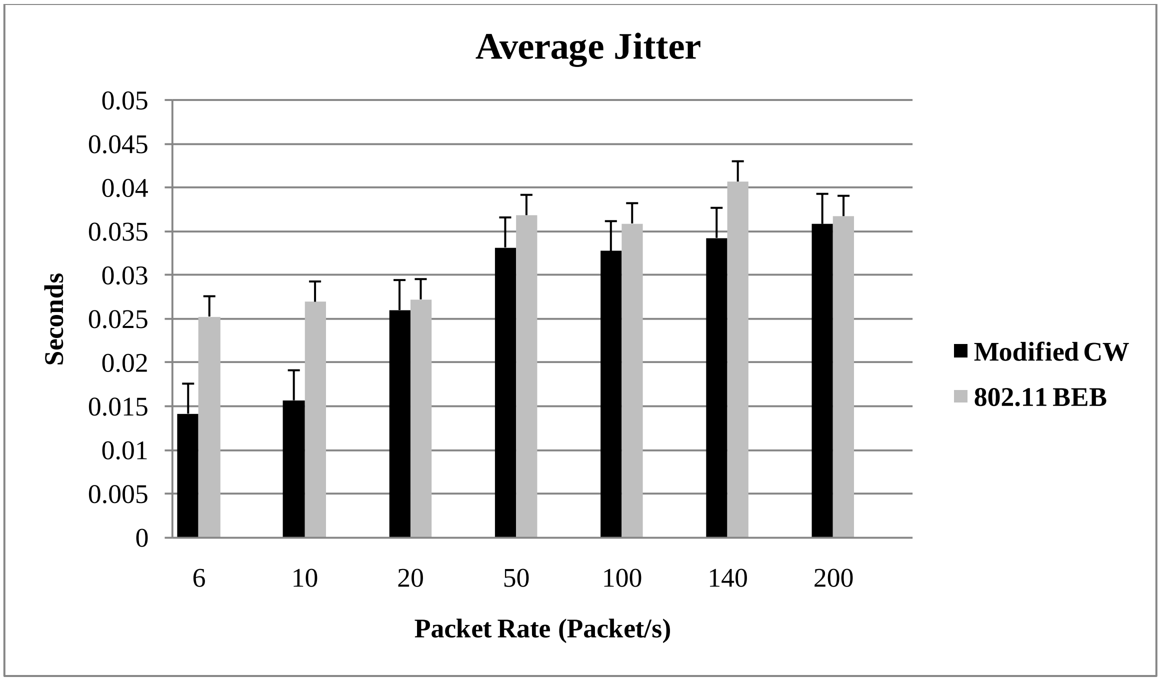

Figure 21: Average Jitter of 802.11 BEB and Modified CW for scenario two – test1.

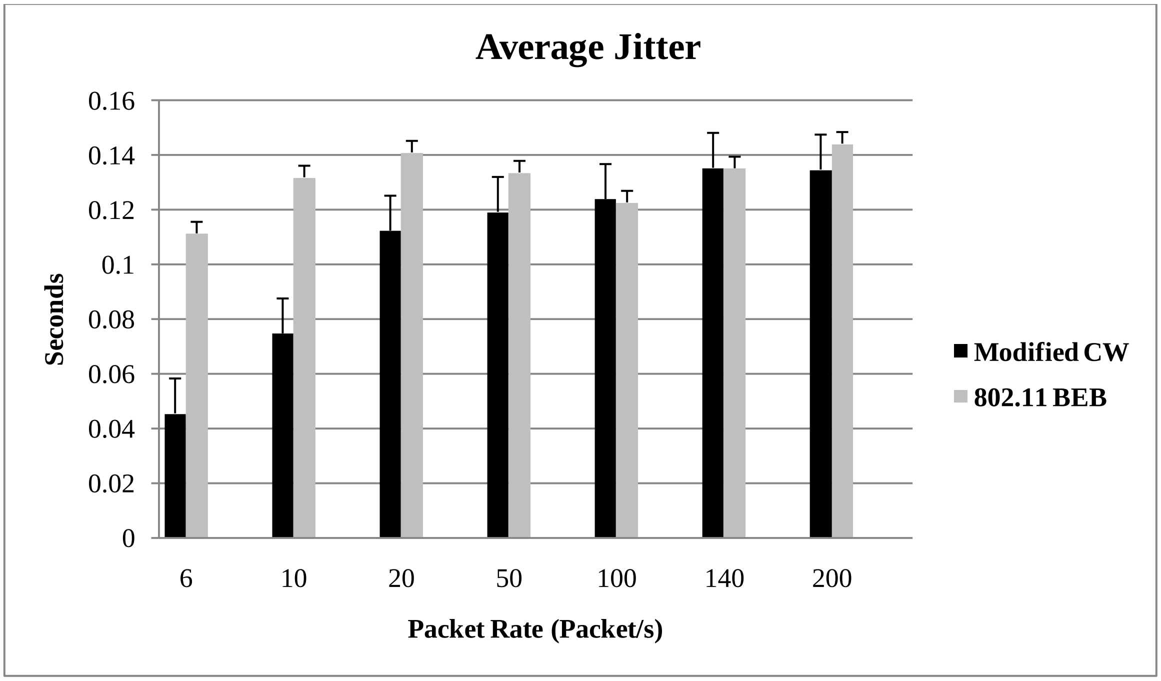

Figure 22: Average Jitter of 802.11 BEB and Modified CW for scenario two – test 2.

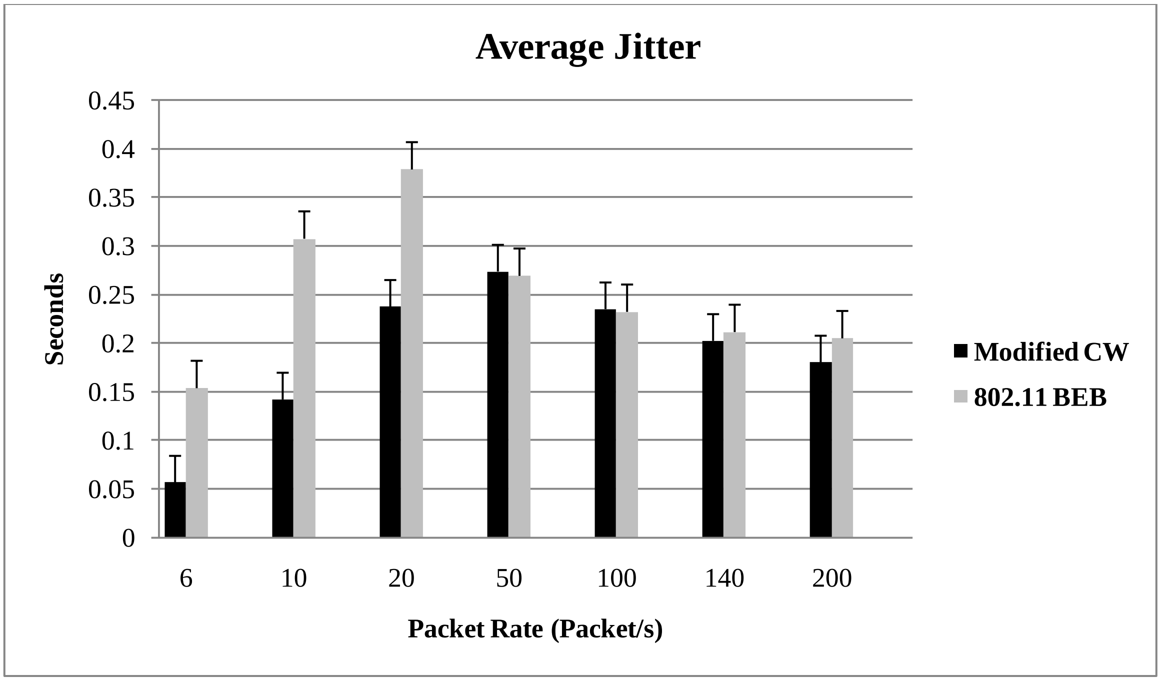

Figure 23: Average Jitter of 802.11 BEB and Modified CW for scenario two – test3.

4.5.2 Average End to End Delay:

The statistics output file in QualNet calculates the average end to end delay for each receiving station; in order to compare the results for both the 802.11 BEB and the Modified CW mechanism the average end to end delay of all receiver stations is calculated. Each scenario is tested 18 times; each time adjusting the total number of packets to be sent by each transmitter station to 10, 100 and 1000 packets described as test 1, test 2 and test 3 respectively for 6 different packet rates. Figures 24 - 29 represent the average end to end delay of both methods:

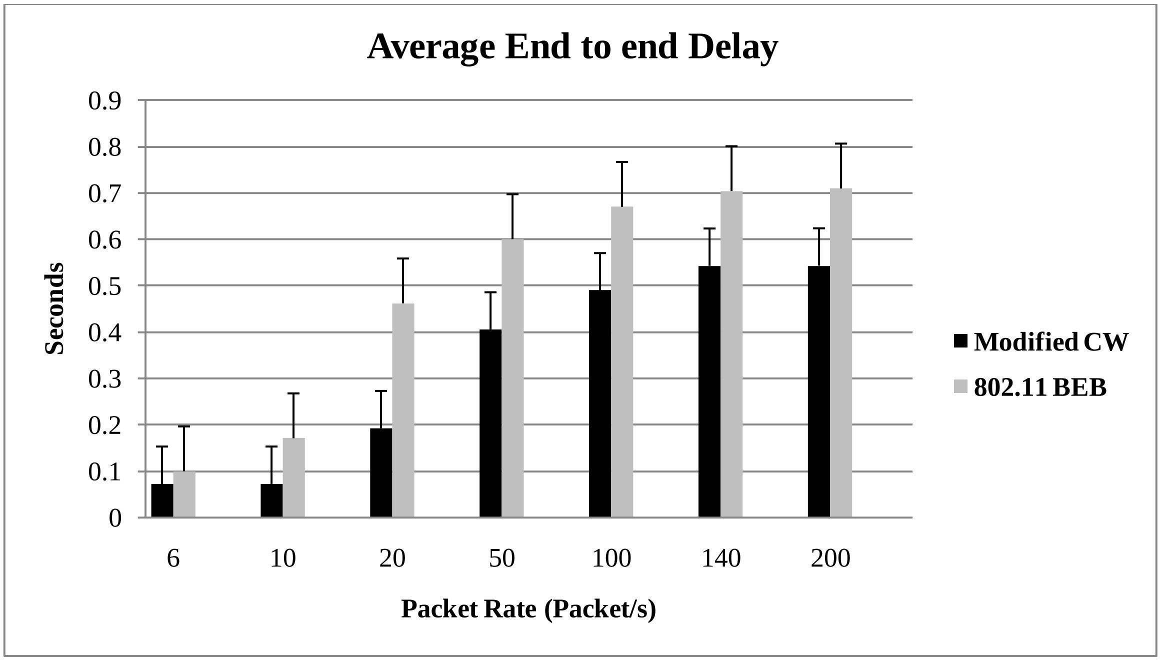

Figure 24: Average end to end delay of 802.11 BEB and Modified CW for scenario one – test 1.

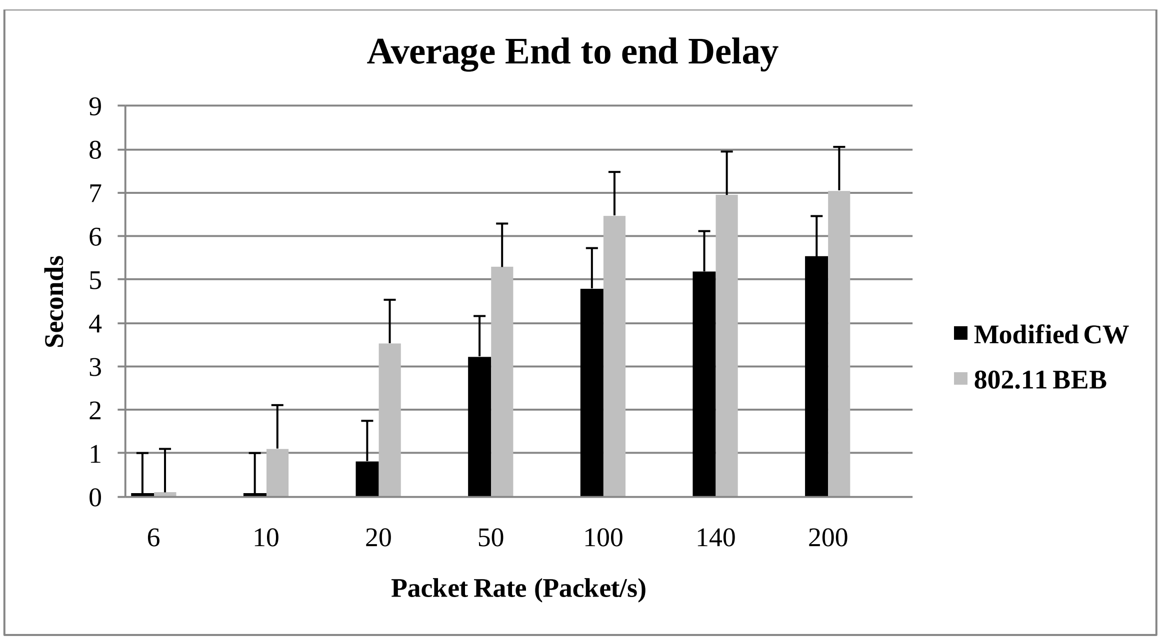

Figure 25: Average end to end delay of 802.11 BEB and Modified CW for scenario one – test 2.

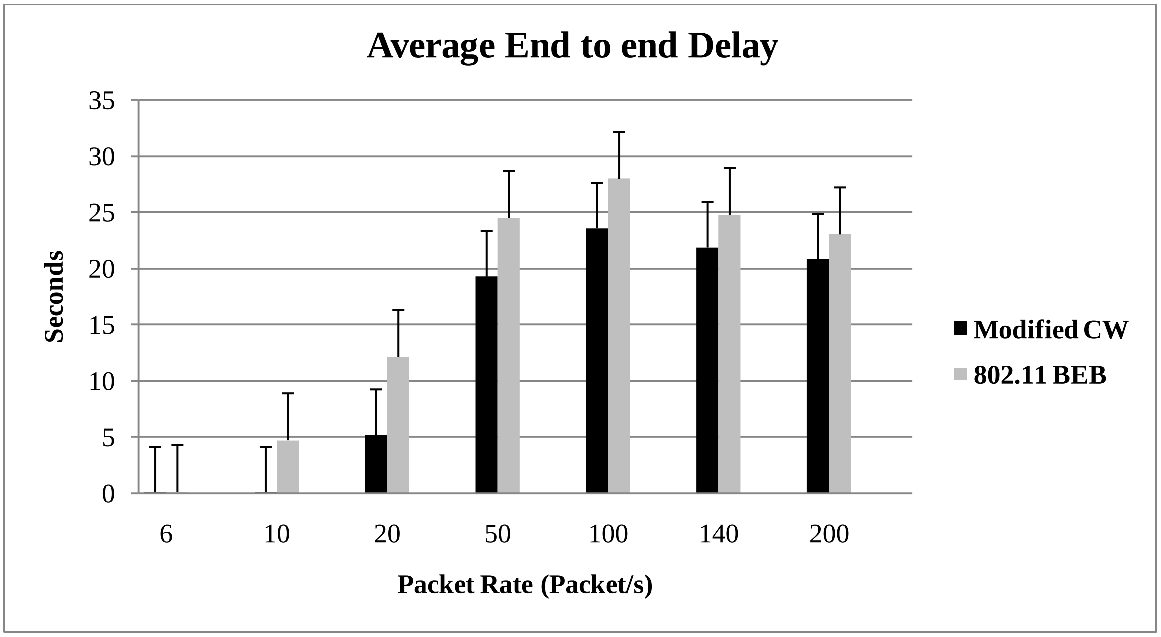

Figure 26: Average end to end delay of 802.11 BEB and Modified CW for scenario one – test 3.

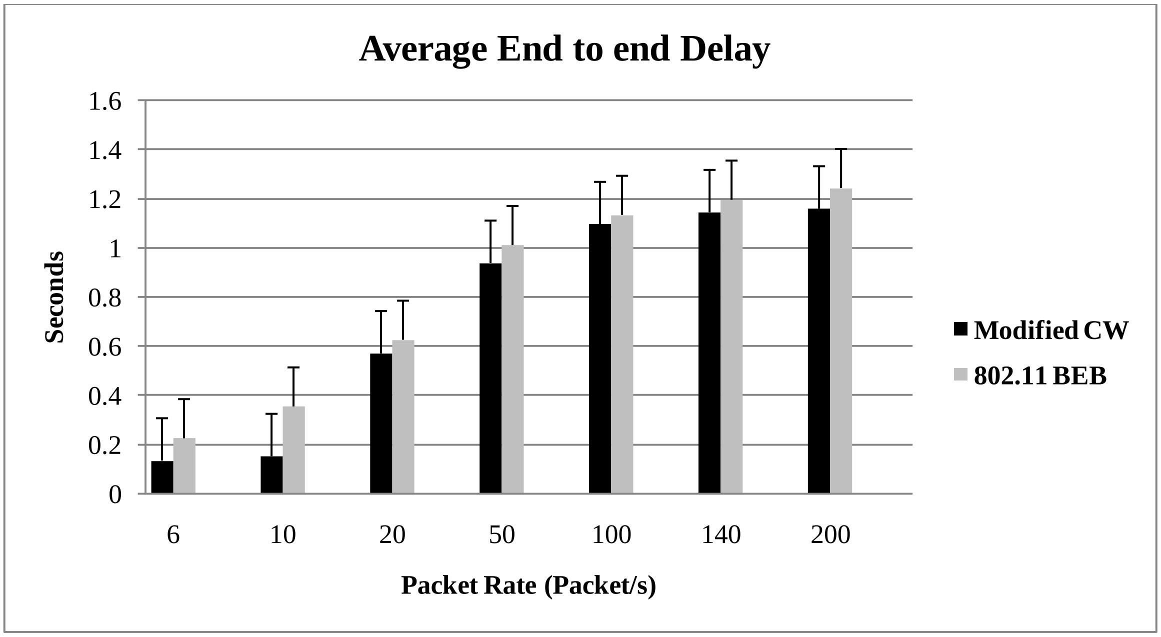

Figure 27: Average end to end delay of 802.11 BEB and Modified CW for scenario two – test 1.

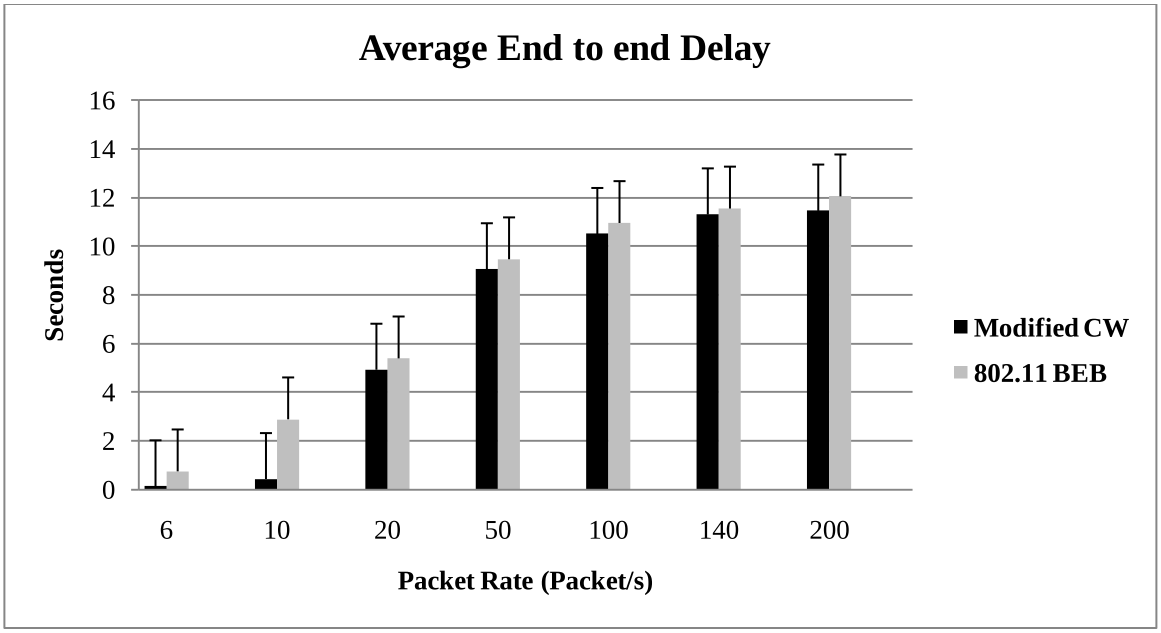

Figure 28: Average end to end delay of 802.11 BEB and Modified CW for scenario two – test 2.

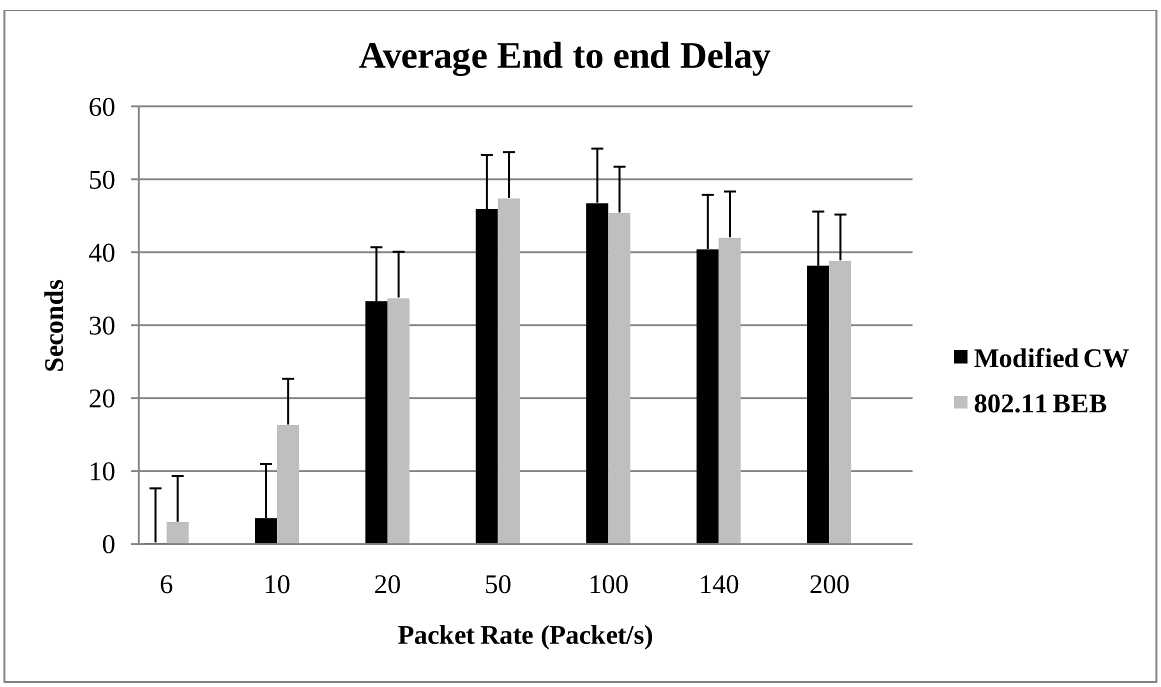

Figure 29: Average end to end delay of 802.11 BEB and Modified CW for scenario two – test 3.

4.5.3 Packets Dropped due to Retransmission Limit:

The statistics output file in QualNet calculates the number of dropped packets for each transmitter station; in order to compare the results for both the 802.11 BEB and the Modified CW mechanism; the total number of dropped packets by all transmitter stations is calculated. Each scenario is tested 18 times; each time adjusting the total number of packets to be sent by each transmitter station to 10, 100 and 1000 packets described as test 1, test 2 and test 3 respectively for 6 different packet rates. Figures 30 - 35 represent the total number of dropped packets due to retransmission limit of both methods:

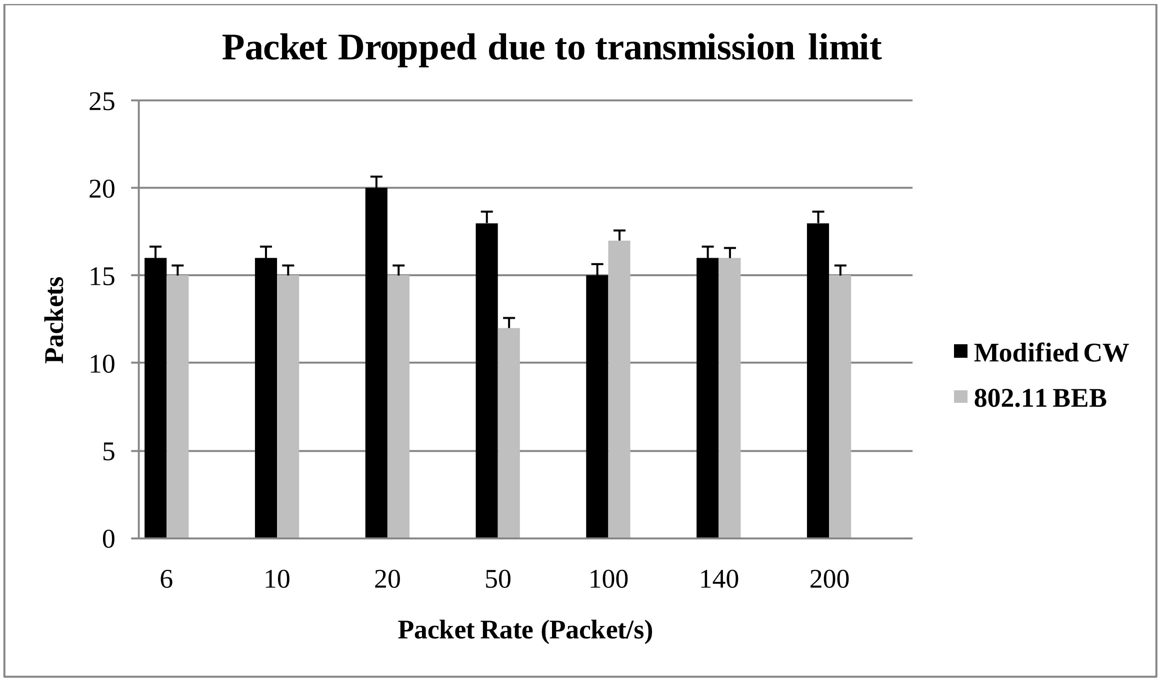

Figure 30: Dropped packets of 802.11 BEB and Modified CW for scenario one – test 1.

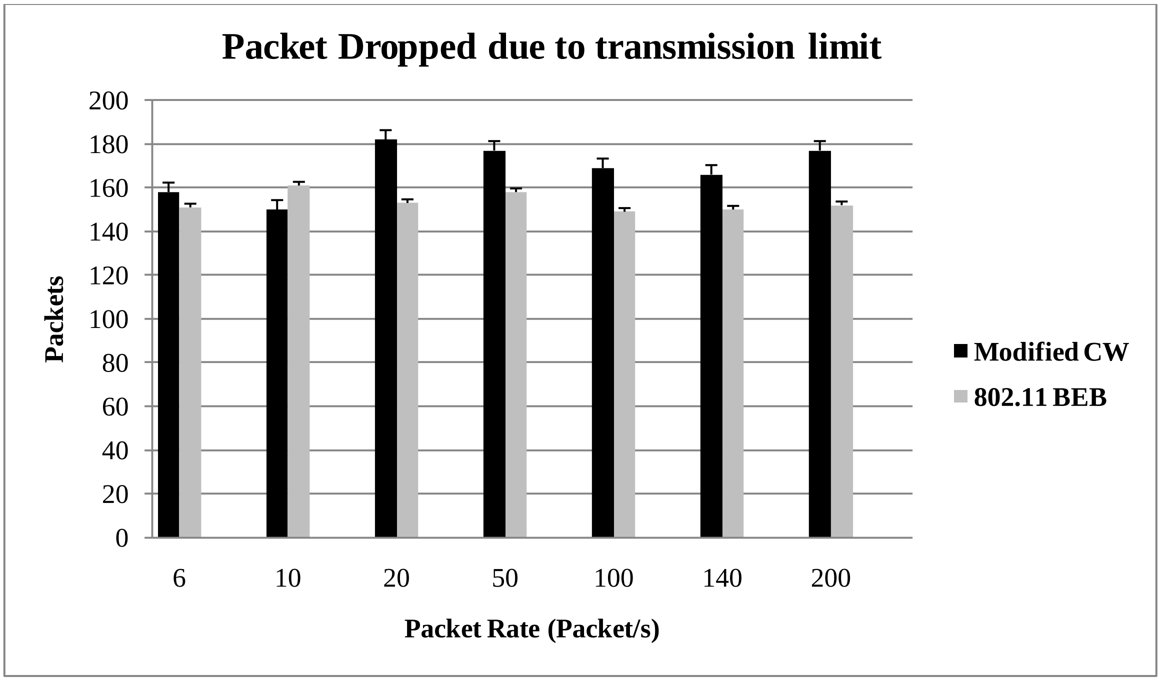

Figure 31: Dropped packets of 802.11 BEB and Modified CW for scenario one – test 2.

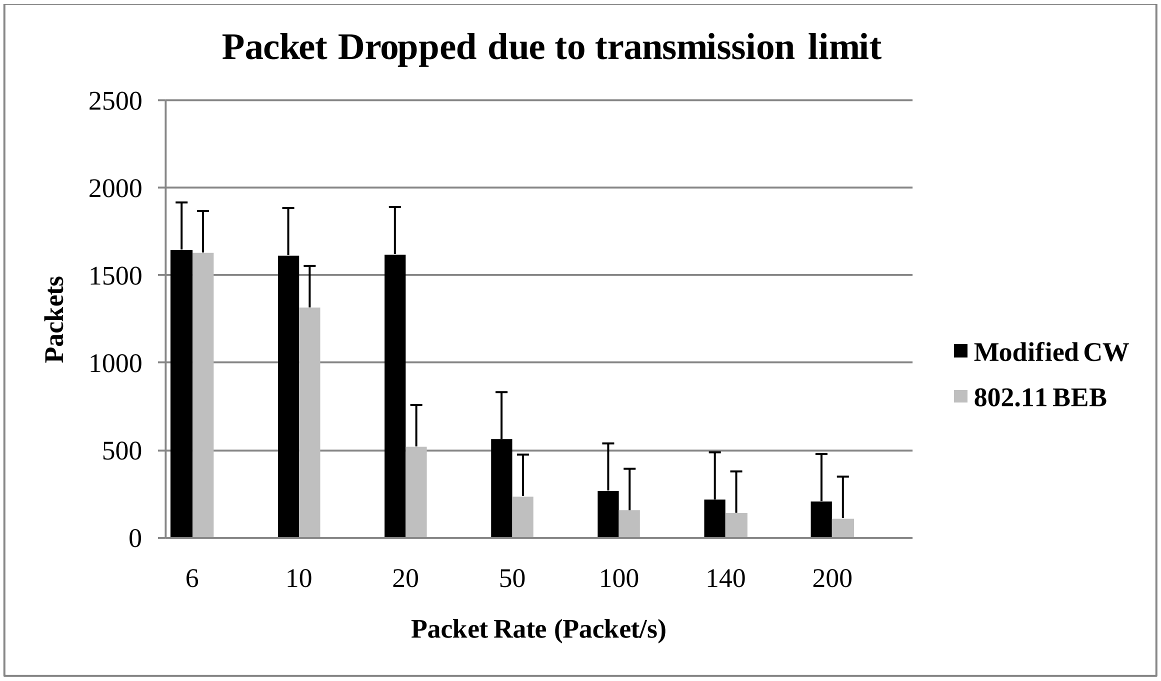

Figure 32: Dropped packets of 802.11 BEB and Modified CW for scenario one – test 3.

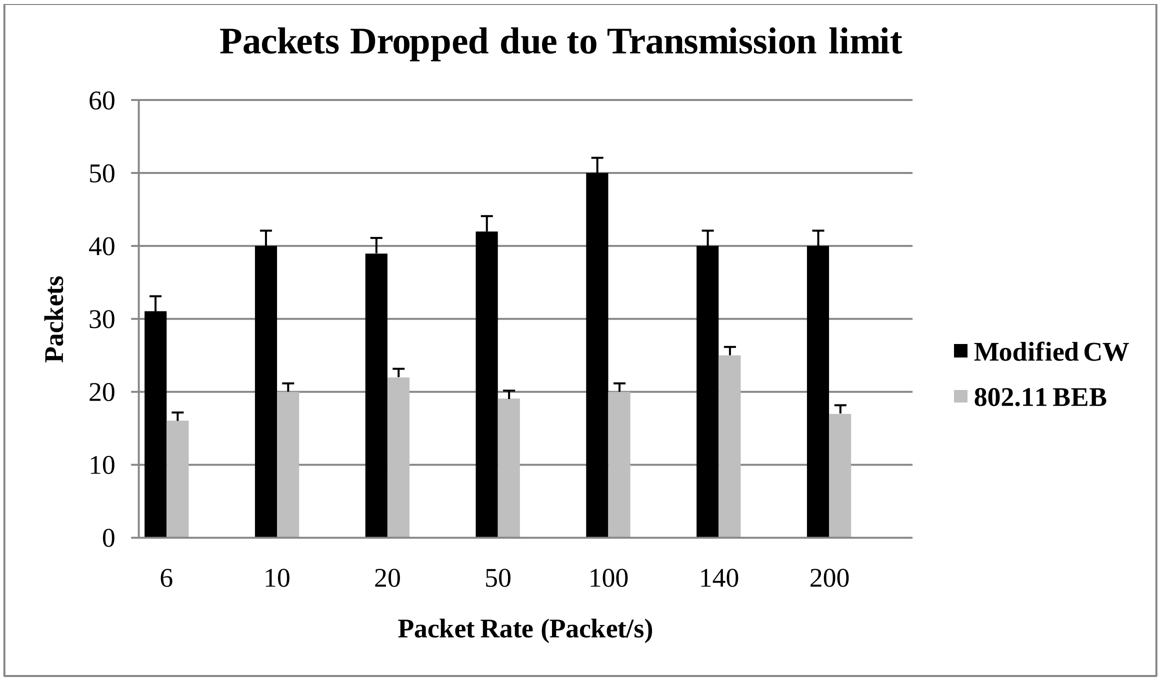

Figure 33: Dropped packets of 802.11 BEB and Modified CW for scenario two – test 1.

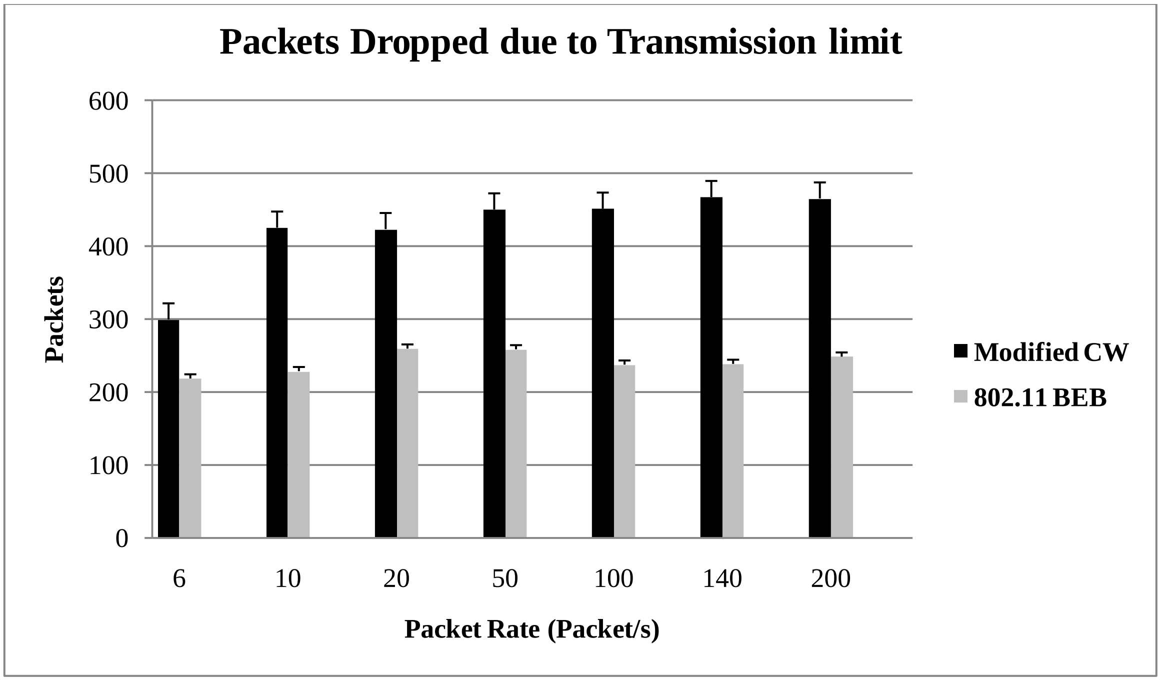

Figure 34: Dropped packets of 802.11 BEB and Modified CW for scenario two – test 2.

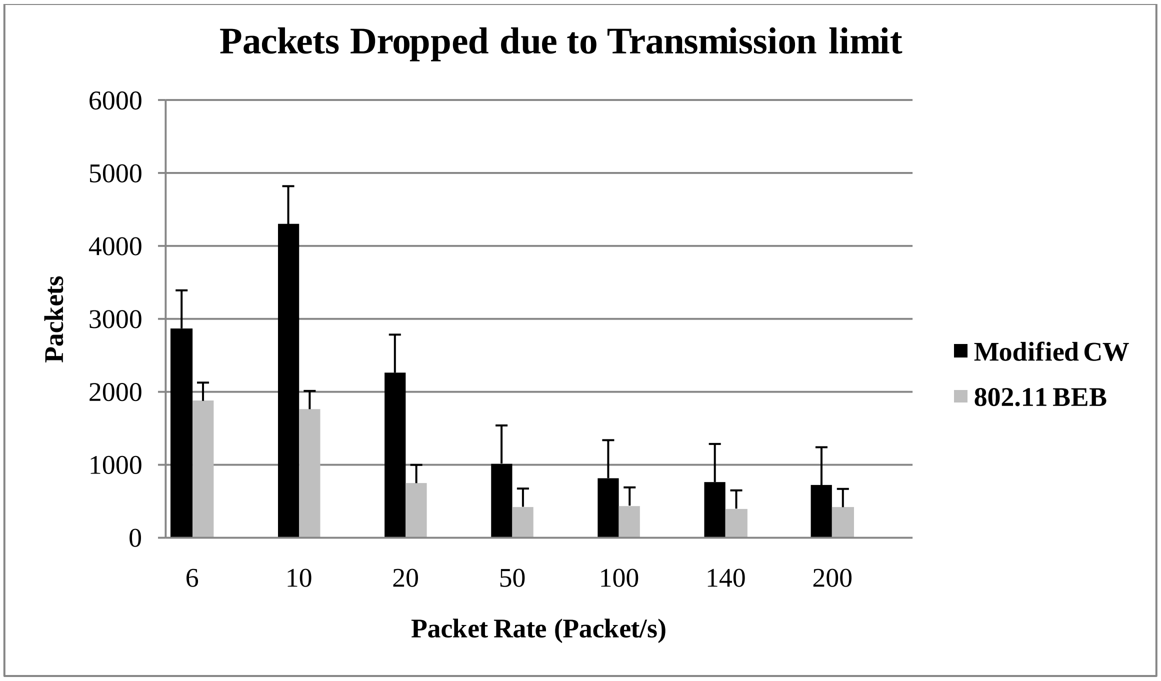

Figure 35: Dropped packets of 802.11 BEB and Modified CW for scenario two – test 3.

4.5.4 PDR:

The statistics output file in QualNet calculates the number of packets sent by each transmitter station and the number of packets received by each receiver station, in this simulation PDR is calculated as the ratio of the total number of packets sent by all transmitters to the total number of packets received by all receivers in order to compared the results for both the 802.11 BEB and the Modified CW mechanism. Each scenario is tested 18 times; each time adjusting the total number of packets to be sent by each transmitter station to 10, 100 and 1000 packets described as test 1, test 2 and test 3 respectively for 6 different packet rates. Figures 36 - 41 represent the PDR of both methods:

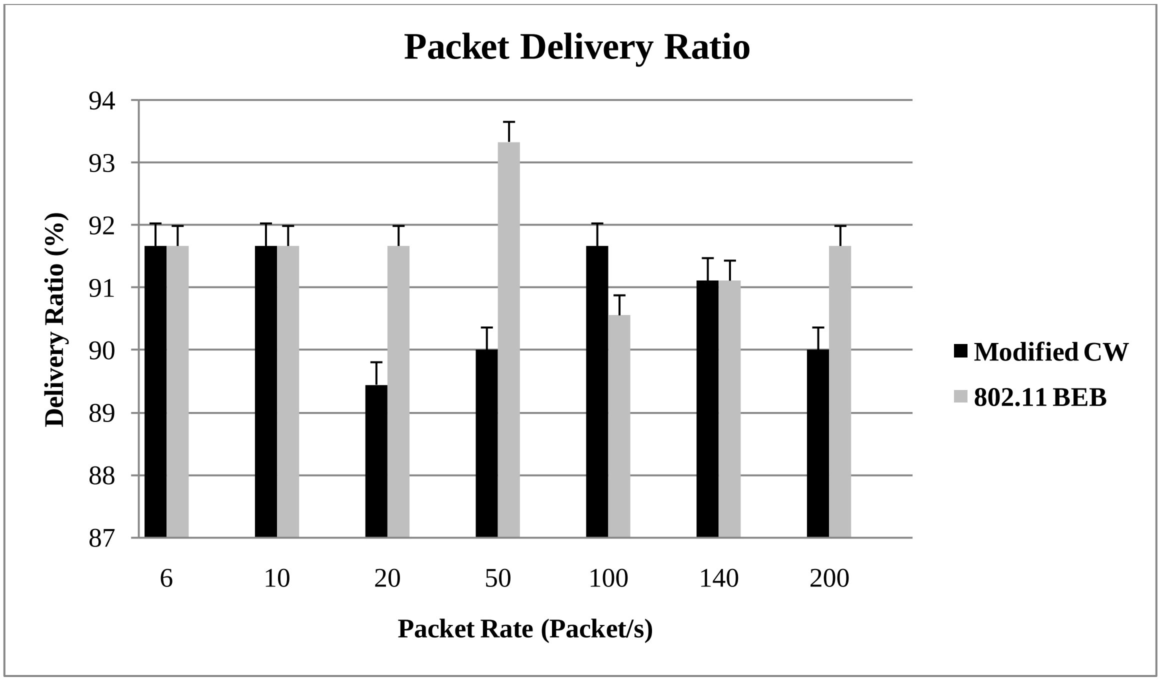

Figure 36: PDR of 802.11 BEB and Modified CW for scenario one – test 1.

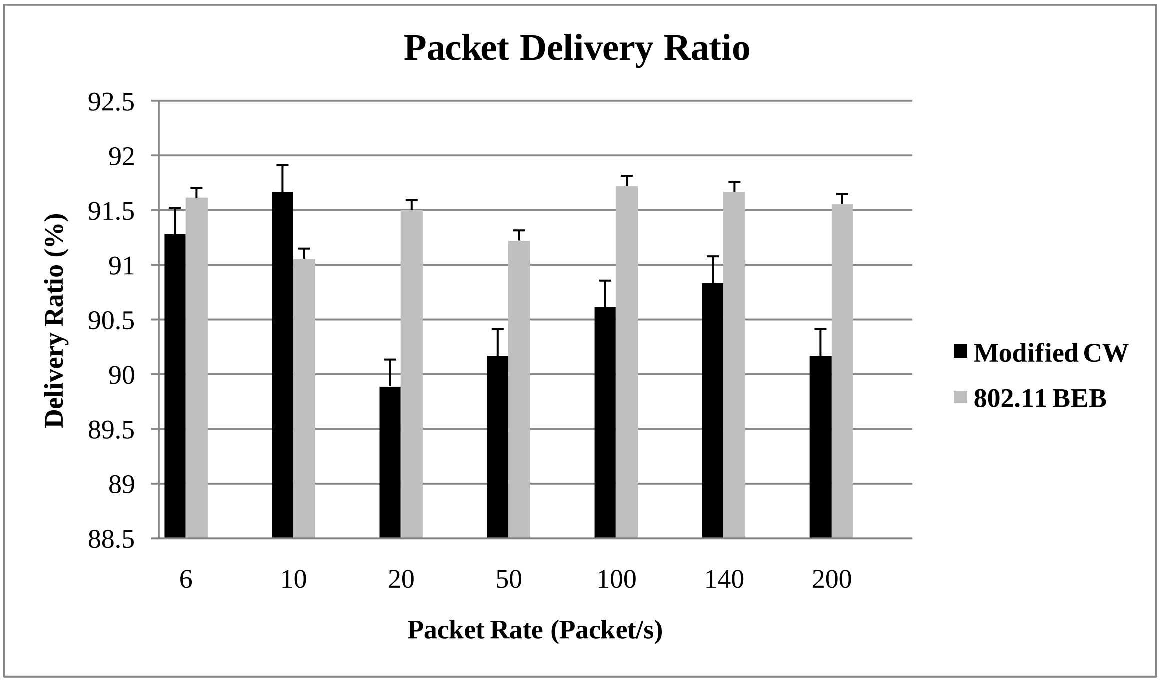

Figure 37: PDR of 802.11 BEB and Modified CW for scenario one – test 2.

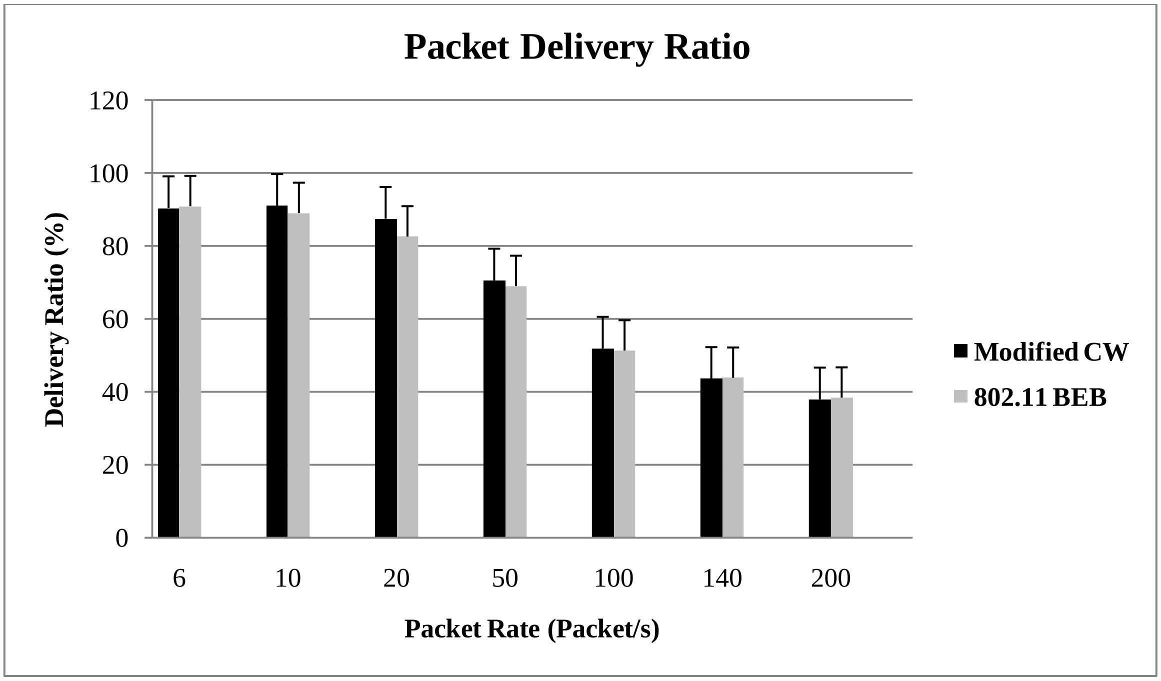

Figure 38: PDR of 802.11 BEB and Modified CW for scenario one – test 3.

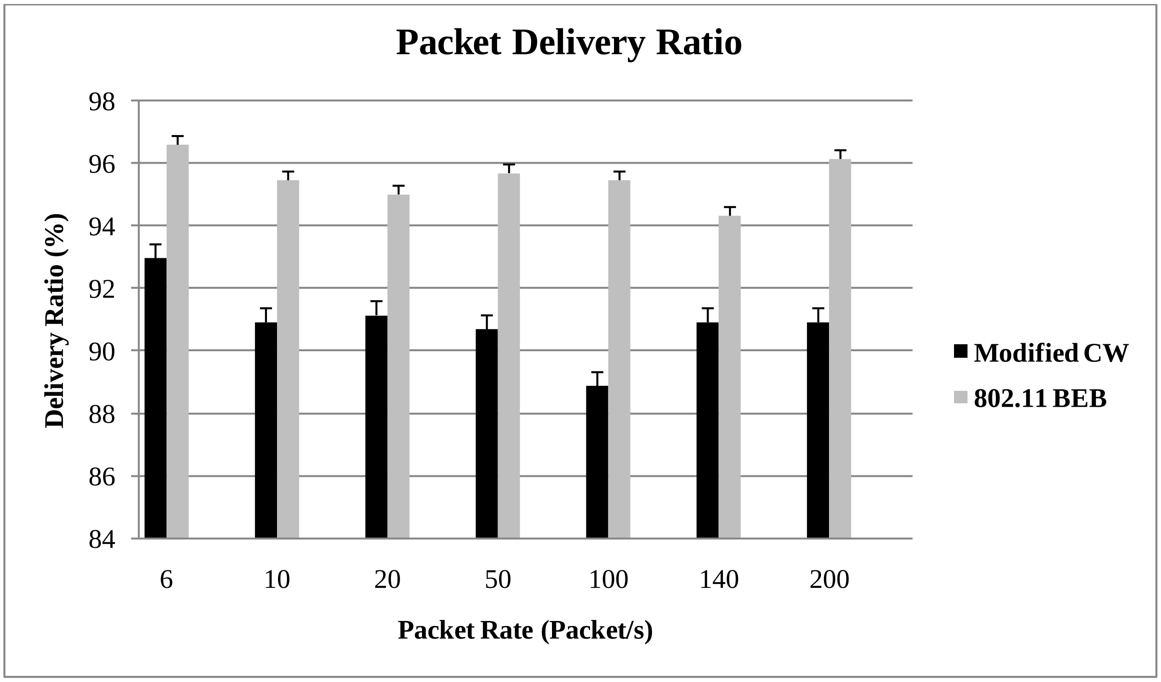

Figure 39: PDR of 802.11 BEB and Modified CW for scenario two – test 1.

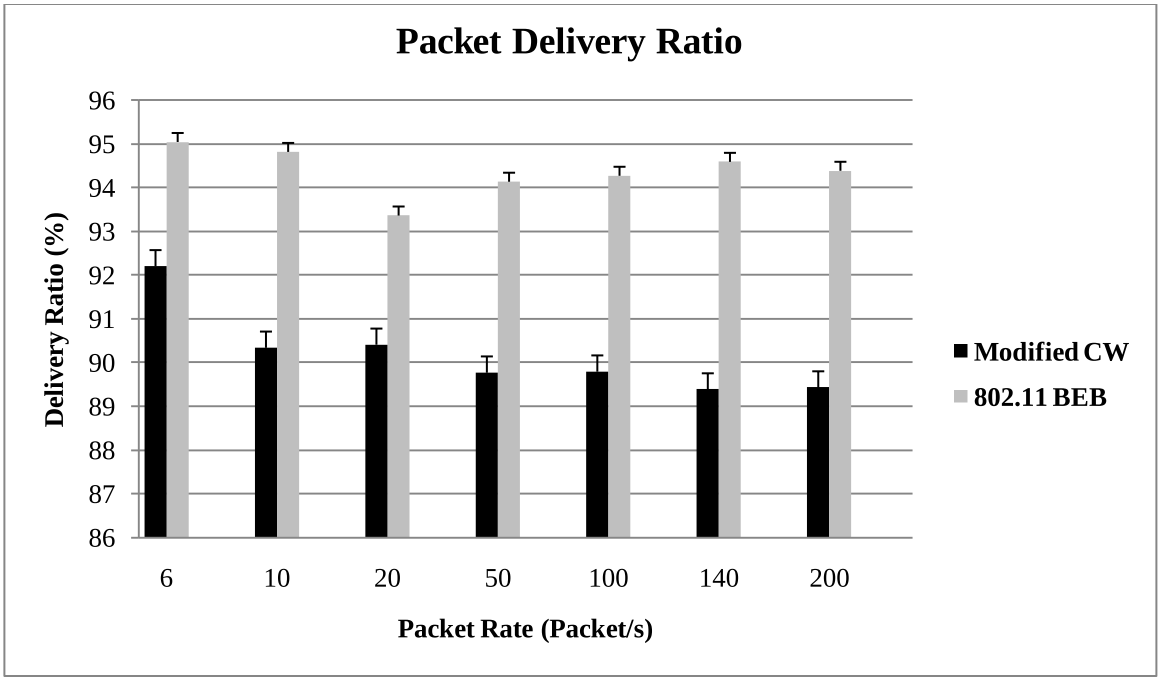

Figure 40: PDR of 802.11 BEB and Modified CW for scenario two – test 2.

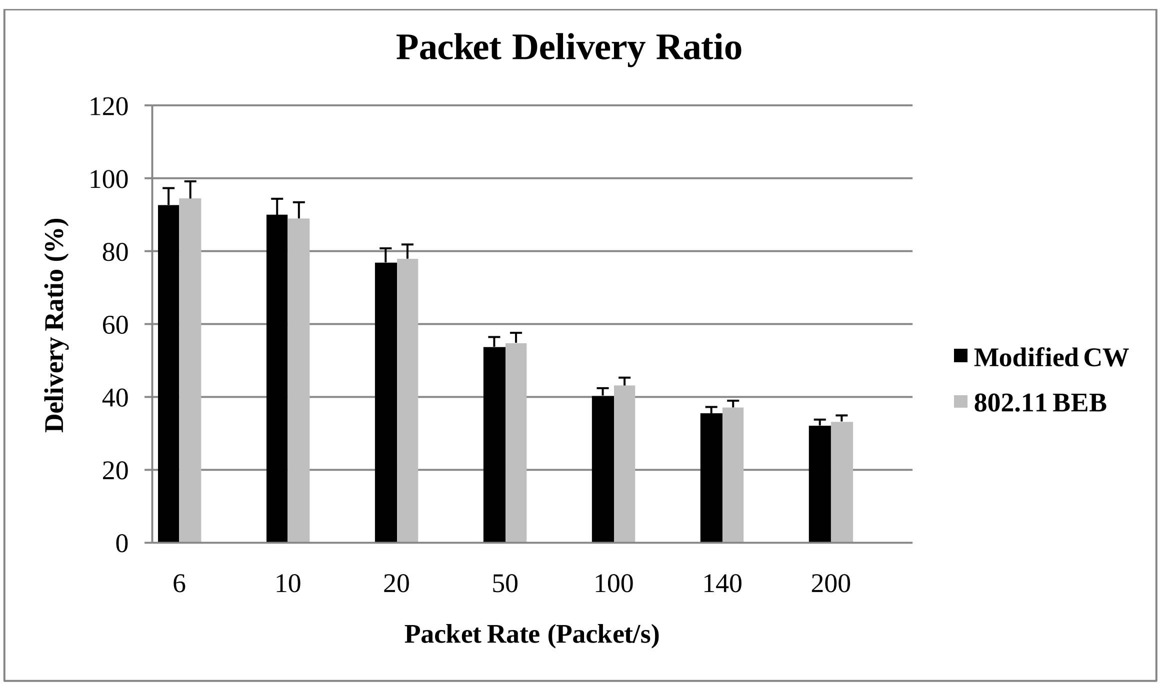

Figure 41: PDR of 802.11 BEB and Modified CW for scenario two – test 3.

4.5.5 Throughput:

The statistics output file in QualNet calculates the throughput for each receiving station; in order to compare the results for both the 802.11 BEB and the Modified CW mechanism; the total throughput of all receiver stations is calculated. Each scenario is tested 18 times; each time adjusting the total number of packets to be sent by each transmitter station to 10, 100 and 1000 packets described as test 1, test 2 and test 3 respectively for 6 different packet rates. Figures 42 - 47 represent the throughput of both methods:

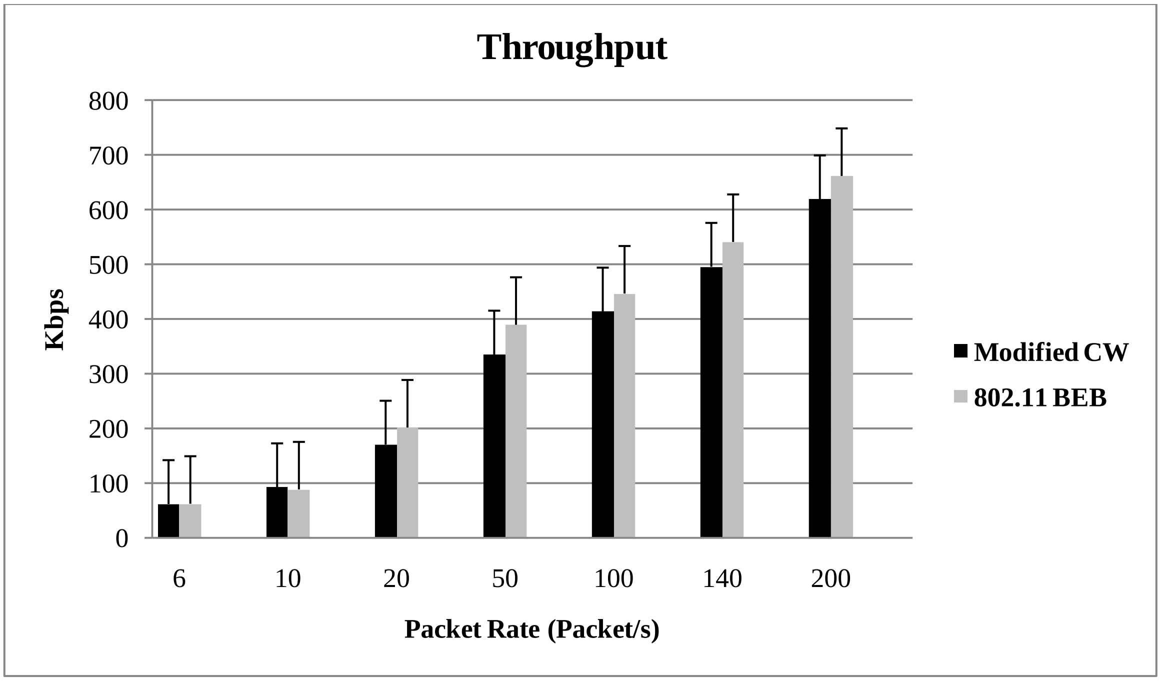

Figure 42: Throughput of 802.11 BEB and Modified CW for scenario one – test 1.

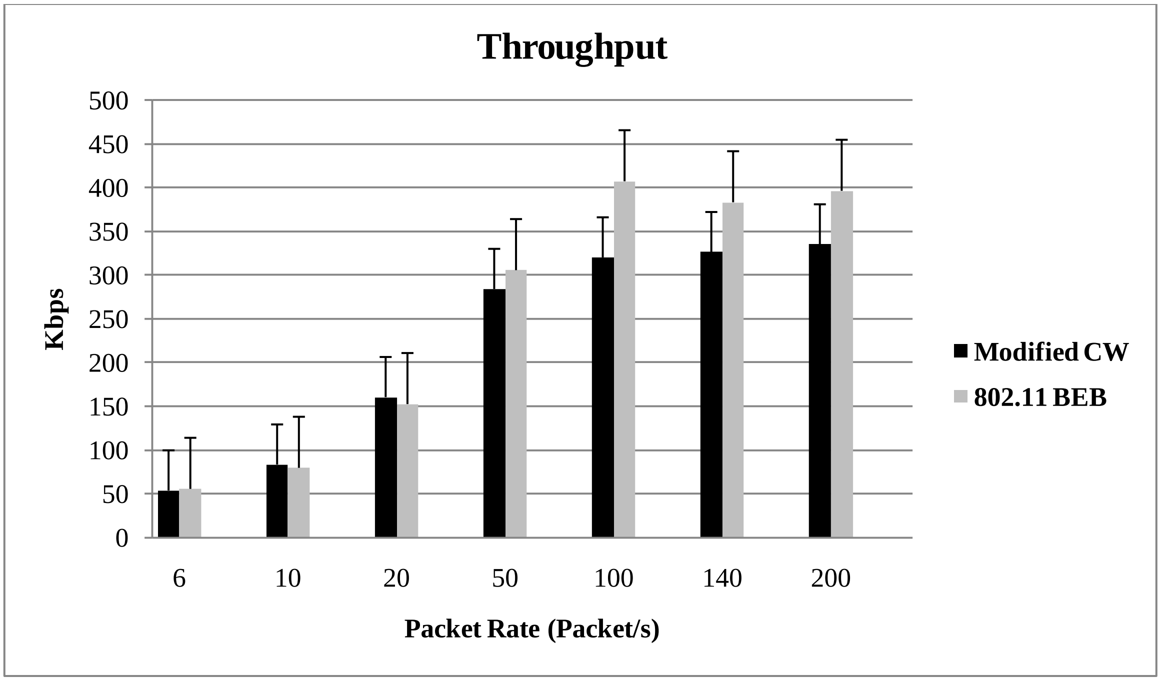

Figure 43: Throughput of 802.11 BEB and Modified CW for scenario one – test 2.

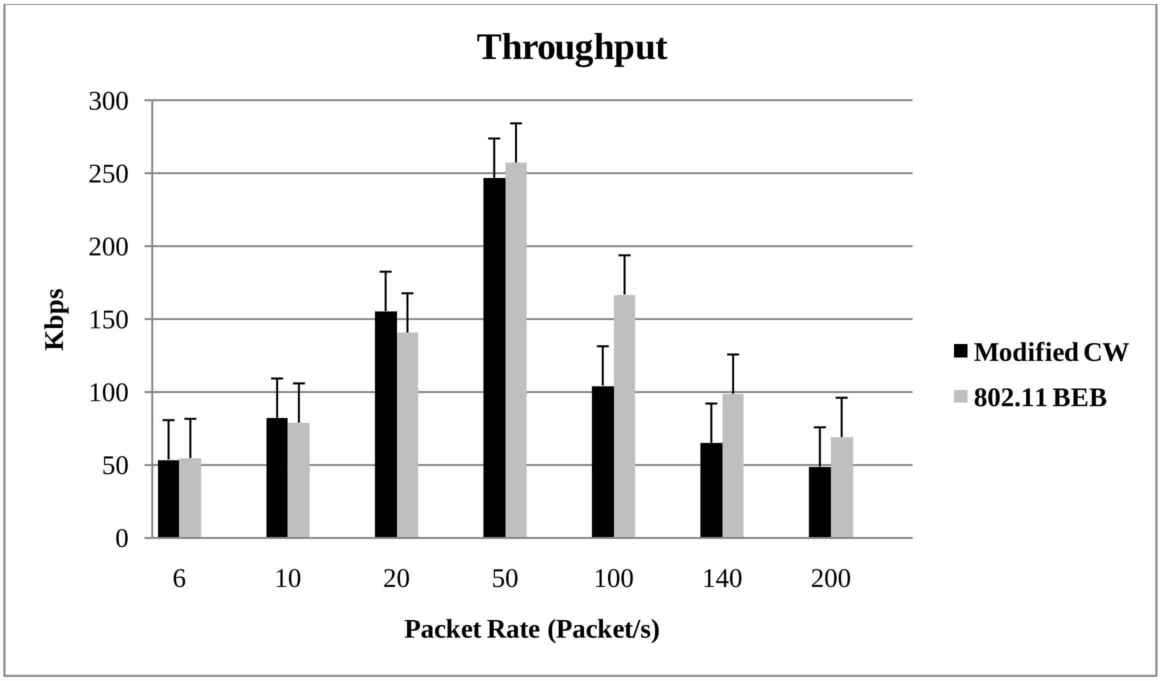

Figure 44: Throughput of 802.11 BEB and Modified CW for scenario one – test 3.

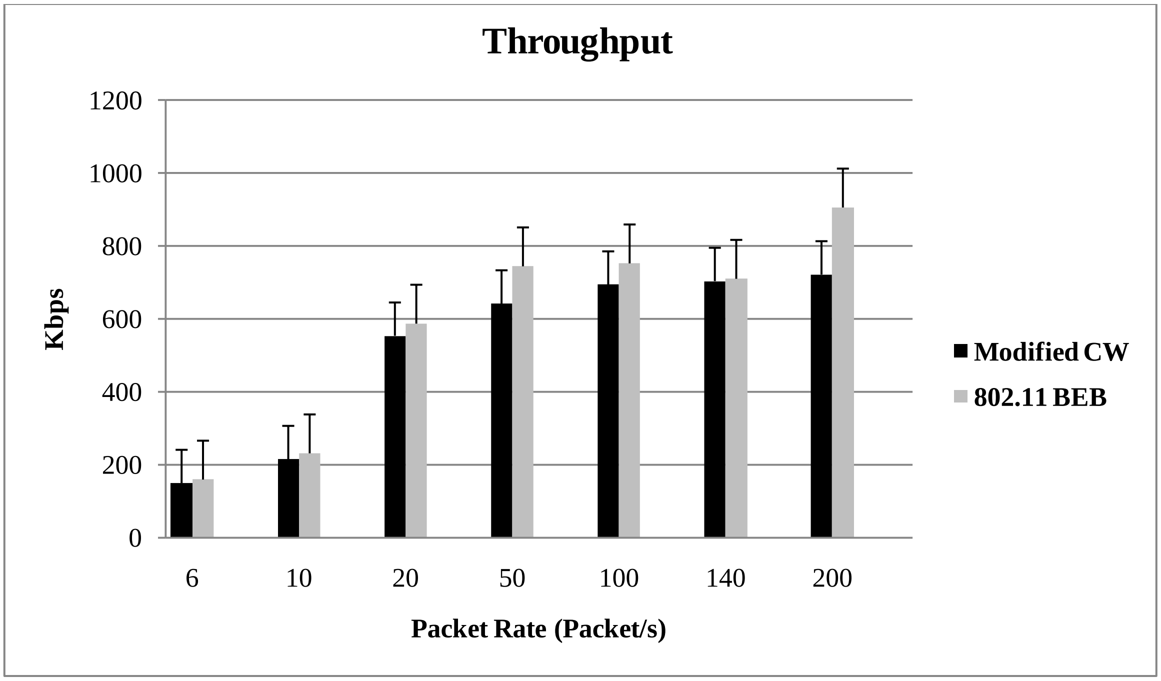

Figure 45: Throughput of 802.11 BEB and Modified CW for scenario two – test 1.

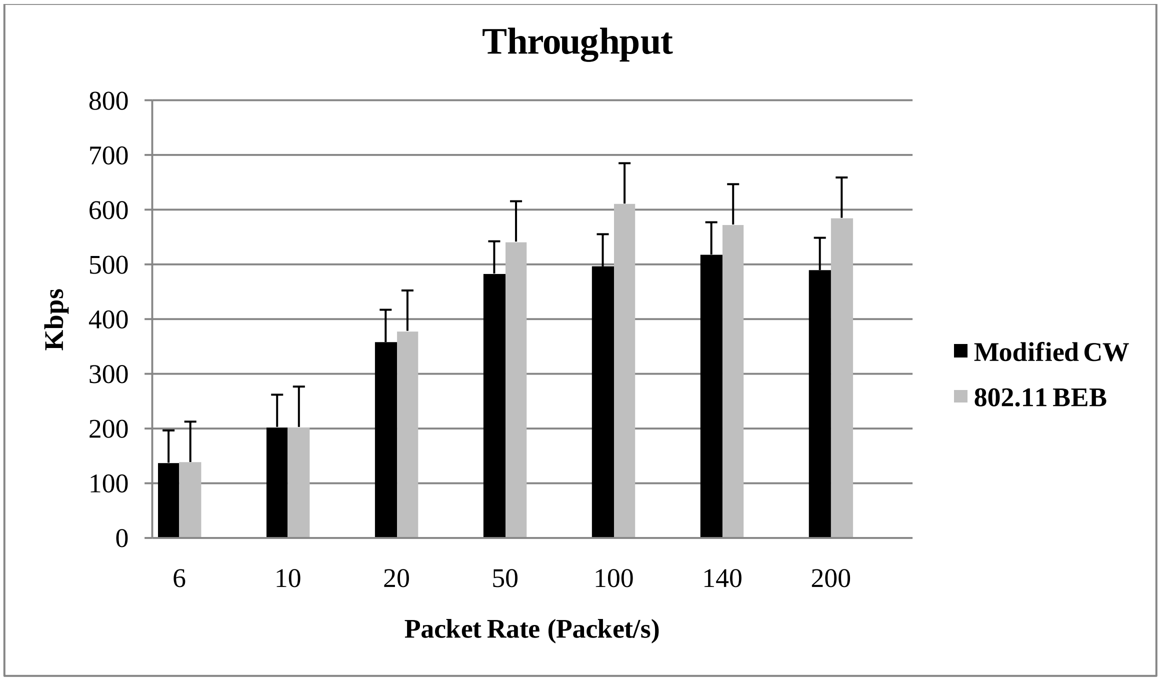

Figure 46: Throughput of 802.11 BEB and Modified CW for scenario two – test 2.

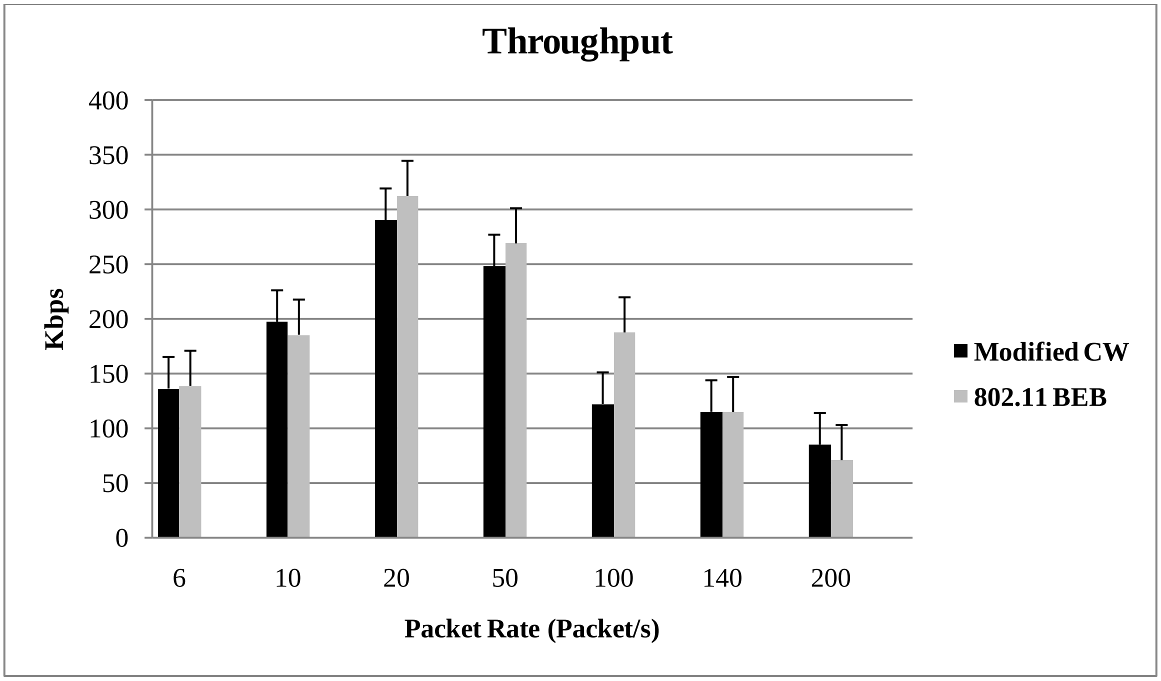

Figure 47: Throughput of 802.11 BEB and Modified CW for scenario two – test 3.

4.6 Results Evaluation:

4.6.1 Average Jitter:

The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the average jitter is shown in Table 3. Results show that in general the Modified CW mechanism outperforms the 802.11 BEB especially at packet rates 6, 10 and 20 PPS where the improvement percentages are high, at other packet rates the Modified mechanism still performs better but with relatively less percentages than those at 6, 10 and 20 PPS. The reason for such drop in performance is the increment in the number of collisions combined with a fatal error in the proposed mechanisms design (will be referred to later). Results also show that as the packet rate increases above 50 PPS the average jitter will drop since nearly all packets will suffer collisions which led to a more

regulated delay times while at low packet rates where only some packets will suffer collisions.

The total number of packets to be sent (10, 100 and 1000 packets) also affected the values of average jitter as clearly shown in Figures 20 and 23 where the average jitter's values dropped at high packet rates; the reason behind such drop is that most packets will be dropped due to retransmission limits and nearly all sent packets will suffer the maximum delay therefore the variation in delay will be almost relative. The improvement percentage values in Table 3 were calculated based on the results shown in Figures 18 – 23.

Table 3: The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the average jitter

		Improvement Percentage of the Modified CW Mechanism in comparison with 802.11 BEB (%)					
Scenario		**1 (20 Stations)**			**2 (50 Stations)**		
No. of Packets sent by each transmitter station		**10**	**100**	**1000**	**10**	**100**	**1000**
Packet Rate (PPS)	**6**	16%	30%	28%	44%	59%	63%
	10	29%	48%	61%	42%	43%	54%
	20	39%	40%	64%	4%	20%	37%
	50	34%	18%	32%	10%	11%	-2%
	100	29%	2%	17%	9%	-1%	-1%
	140	32%	13%	-0.3%	16%	-0.1%	4%
	200	5%	- 6%	6%	2%	`7%	12%

Note: underlined results preceded by the (-) sign represents a decrement in performance.

Results in Table 3 also show that increasing the number of stations from 20 to 50 stations caused the improvement percentage of the Modified CW mechanism to increase at packet rates 6, 10 and 200 PPS. Though the Modified CW mechanism still performed better at 20, 50, 100 and 140 PPS the improvement percentage was decreased. Increasing the total number of sent packets by each transmitter station increased the improvement percentage at 6, 10, 20 and 200 PPS while the percentage was decreased at 50, 100 and 140 PPS.

In figures 18 - 23 it is shown that increasing the number of stations had a slight effect on the average jitter values resulted when employing the Modified CW mechanism; the improvement percentage change was mainly due to the variation of the average jitter values resulted when employing the 802.11 BEB.

Reducing the average jitter is an important improvement in DCF especially in real time application where the aim is to reach a jitter value of zero; the Modified CW mechanism reduced the average jitter by employing a uniform delay on packets for all stations, a transmitter station will only wait for 0 - 64 slots before successfully transmit a packet; in the 802.11 BEB the delay will vary between 0 – CWmax depending on the station's CW value at that time.

4.6.2 Average End to End Delay:

The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the average end to end delay is shown in Table 4. Results show that in general the Modified CW mechanism outperforms the 802.11 BEB especially at packet

rates 6, 10 and 20 PPS. The improvement percentage values in Table 4 were calculated based on the results shown in Figures 24 – 29.

Table 4: The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the average end to end delay.

		Improvement Percentage of the Modified CW Mechanism in comparison with 802.11 BEB (%)					
Scenario		**1 (20 Stations)**			**2 (50 Stations)**		
No. of Packets sent by each transmitter station		**10**	**100**	**1000**	**10**	**100**	**1000**
Packet Rate (PPS)	**6**	27%	23%	18%	40%	82%	96%
	10	58%	93%	98%	57%	85%	79%
	20	58%	77%	57%	9%	9%	2%
	50	33%	39%	21%	7%	4%	3%
	100	27%	26%	16%	3%	4%	<u>-3%</u>
	140	23%	25%	12%	4%	2%	4%
	200	23%	22%	10%	7%	5%	2%

Note: underlined results preceded by the (-) sign represents a decrement in performance.

Results in Table 4 also show that as the number of station increased from 20 to 50; the improvement percentage of the Modified CW mechanism increased at packet rates 6 and 10 PPS, though the improvement percentage was decreased at 20, 50, 100, 140 and 200 PPS the Modified CW still performed better.

Increasing the total number of sent packets by each transmitter station resulted an increase in the improvement percentage of the Modified CW mechanism at packet rates 6 and 10 PPS while it had a very slight affect on the improvement percentage of the Modified CW mechanism when the packet rates was 20, 50, 100, 140 and 200 PPS.

In figures 24 – 29 it is shown that while increasing the number of stations from 20 to 50 had a little affect on the average end to end delay values, increasing the total number of sent packets caused an enormous increase on the average end to end delay values.

It is also shown that the Modified CW mechanism performance's is better in scenario 1 where the total number of station is 20 than its in scenario 2 where the total number of stations is 50 due to the failure of the proposed mechanism to handle collisions at 2^{nd} and 3^{rd} retransmissions.

4.6.3 Packets Dropped Due to Retransmission Limit:

The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the number of dropped packets due to retransmission limit is shown in Table 5; results show that in general the Modified CW mechanism drops a large number of packets due to retransmission limit compared to the 802.11 BEB which drops an acceptable rate of packets due to retransmission limit. To improve the Modified CW mechanism, a solution to the high rate of dropped packet due to retransmission limit will be discussed in the future work highlights. Furthermore as mentioned earlier an error in the algorithm design of the proposed mechanism led to inefficiency in handling collisions at the 2^{nd} and 3^{rd} retransmissions caused its performance to drop.

The improvement percentage values in Table 5 were calculated based on the results shown in Figures 30 – 35.

Table 5: The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the number of packets dropped due to transmission limit.

		Improvement Percentage of the Modified CW Mechanism in comparison with 802.11 BEB (%)					
Scenario		**1 (20 Stations)**			**2 (50 Stations)**		
No. of Packets sent by each transmitter station		**10**	**100**	**1000**	**10**	**100**	**1000**
Packet Rate (PPS)	**6**	-7%	-5%	-1%	-94%	-37%	-53%
	10	-7%	7%	-23%	-100%	-86%	-144%
	20	-33%	-19%	-212%	-77%	-63%	-203%
	50	-50%	-12%	-138%	-121%	-74%	-142%
	100	12%	-13%	-73%	-50%	-90%	-86%
	140	0%	-11%	-55%	-60%	-96%	-93%
	200	-20%	-16%	-88%	-135%	-88%	-73%

Note: underlined results preceded by the (-) sign represents a decrement in performance.

Results in Table 5 also show that as the number of station increased from 20 to 50; the Modified CW mechanism suffers an increase in the rate of dropped packets due to retransmission limit; the rate was far from being acceptable at any packet rate which indicates that the Modified CW mechanism suffers a huge limitation regarding this particular issue. Increasing the number of sent packets by each transmitter also had the same effect on the proposed mechanism.

The high rate of dropped packets due to retransmission limit in the Modified CW mechanism will hugely affect the performance of the proposed Modified CW mechanism regarding the PDR and throughput which indicates that solving this problem will enhance the performance of the proposed Modified CW mechanism.

4.6.4 PDR:

The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the PDR shown in Table 6; results show that in general the Modified CW mechanism's performance was less efficient than the 802.11 BEB performance.

The improvement percentage values in Table 6 were calculated based on the results shown in Figures 36 – 41.

Table 6: The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding PDR.

		Improvement Percentage of the Modified CW Mechanism in comparison with 802.11 BEB (%)					
Scenario		1 (20 Stations)			2 (50 Stations)		
No. of Packets sent by each transmitter station		10	100	1000	10	100	1000
Packet Rate (PPS)	6	0%	-0.3%	-1%	-4%	-3%	-2%
	10	0%	1%	2%	-4%	-5%	1%
	20	-2%	-1%	6%	-4%	-3%	-1%
	50	-4%	-2%	2%	-5%	-5%	-2%
	100	1%	-1%	1%	-7%	-5%	-6%
	140	0%	-1%	-1%	-4%	-6%	-4%
	200	-2%	-2%	-1%	-5%	-5%	-3%

Note: underlined results preceded by the (-) sign represents a decrement in performance.

As shown in Table 6; increasing the total number of station from 20 to 50 had a slightly dreadful effect on the Modified CW mechanism's performance while increasing the total

packets to be sent had a slight effect on the PDR, the proposed mechanism performed better mainly at 10 and 20 PPS when employed in scenario one.

4.6.5 Throughput:

The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the throughput shown in Table 7; results show that in general the Modified CW mechanism performed better at 10 PPS in both scenarios while the 802.11 BEB performed better at 50, 100 PPS in both scenarios.

The improvement percentage values in Table 6 were calculated based on the results shown in Figures 42 – 47.

Table 7: The improvement percentage of the Modified CW mechanism in comparison with the 802.11 BEB regarding the Throughput.

		Improvement Percentage of the Modified CW Mechanism in comparison with 802.11 BEB (%)					
Scenario		**1 (20 Stations)**			**2 (50 Stations)**		
No. of Packets sent by each transmitter station		**10**	**100**	**1000**	**10**	**100**	**1000**
Packet Rate (PPS)	**6**	-1%	-3%	-2%	-6%	-1%	-12%
	10	5%	5%	4%	-7%	1%	6%
	20	-16%	6%	10%	-6%	-5%	-7%
	50	-14%	-7%	-4%	-14%	-11%	-8%
	100	-7%	-21%	-37%	-8%	-19%	-35%
	140	-8%	-15%	-34%	-1%	-10%	1%
	200	-6%	-15%	-30%	-20%	-16%	20%

Note: underlined results preceded by the (-) sign represents a decrement in performance.

As shown in Table 7; while increasing the total number of station from 20 to 50 had a slight effect on the performance of both mechanisms at 10, 50 and 100 PPS; its effect was clearly shown at packet rates 6, 20, 140 and 200 PPS.

Increasing the total packets to be sent by each transmitter station improved the performance of the proposed mechanism at packet rates 10, 140 and 200 PPS in scenario two; and caused the performance to drop at 20, 50, 140 and 200 PPS in scenario 1.

Throughput results of the proposed Modified CW mechanism is hugely affected by the high rate of dropped packets due to retransmission limit; in general the proposed mechanism successfully reduced the average jitter and the average end to end delay by a tremendous amount compared to the 802.11 BEB; regarding the rest performance metrics the proposed mechanism performs better at low packet rate such as 10 PPS; at such packet rate the proposed mechanism performs better as the total number of station increases; while at high packet rates such as 100 the proposed mechanism suffers by facing a high rate of dropped packets due to retransmission limit.

CHAPTER FIVE

CONCLUSION & FUTURE WORK

This Thesis proposes a Modified CW control mechanism that aims to solve the current problems in 802.11 BEB which is used by DCF to control and regulate the channel access among stations, the proposed Mechanism was tested in simulation versus the 802.11 BEB; in this chapter concludes the work presented and highlights the future work.

5.1 Conclusion:

The proposed mechanism employs a unique technique to regulate and control the channel access by solving collisions once they occur instead of just increasing the CW size. The proposed mechanism doe not employ an increase or decrease on the CW size; the size of CW is fixed for all stations which provide a fair and equal channel access chance for all stations.

The proposed mechanism does not involve any kind of information gathering or channel state monitoring; it also aims to reduce the delay by reducing the time each station must wait before starting the transmission; this is achieved mainly due to preventing the CW values from reaching high values.

The performance of the proposed mechanism was evaluated versus the performance of the 802.11 BEB in different network conditions with respect to; number of stations, traffic rate and total number of sent packets; the performance was evaluated based on different

performance metrics such as; average jitter, average end to end delay, number of dropped packets, PDA and throughput.

Results showed that the proposed mechanism was able to reduce the average jitter by 50%, the average end to end delay by 80% and the throughput by 5% in lightly loaded networks while the improvement percentage was less than that in heavy loaded networks. In general the proposed mechanism performed better in lightly loaded network than it performed in heavy loaded networks due the increment in packets dropped due to retransmission limit rate.

The 802.11's BEB employs a retransmission limit policy to prevent a massive increase in the CW size, the retransmission limit for short packets is 7 while its 4 retries for long packets; this policy improves the performance of the 802.11 BEB by reducing the delay however it affected the performance of the proposed mechanism since the proposed mechanism does not involve increasing the CW size after a failure retransmission; as a result the performance of the proposed mechanism suffered in respect to throughput and PDR, solving this limitation will boost the performance of the proposed mechanism and provide a better performance indicators.

This Thesis has also shown the increasing the network size (number of stations) have a slight affect in the performance of the Modified CW mechanism compared to its effect on the performance of the 802.11 BEB; which indicates the flexibility of the proposed mechanism over the latter.

Finally in this work the average end to end delay was highlighted as the most important factor in measuring the performance of any mechanism or method aims to replace the 802.11 BEB; the performance of any suggested mechanism or method will be hugely affected by its ability to reduce the average end to end to delay more than any other factor; the new trend in CW research should aim toward the delay instead reducing the total number of collisions.

5.2 Future Work:

As mentioned earlier the proposed mechanism suffers an important limitation regarding the dropped packets due to retransmission limit; to solve this limitation a new retransmission policy should be introduced to better suit the proposed mechanism rather than relying on the 802.11 policy.

Another limitation was also discovered in the proposed mechanism and its clearly shown in figure 14, the backoff timer calculations after a collision occur will not solve a collision in the 2^{nd} and 3^{rd} retransmission; this setback was not noticed when designing the proposed mechanism; if a collision occurs in the first transmission it will be successfully handled in the 1^{st} retransmission however based on the calculation in figure 14 the collision in the 1^{st} retransmission will not be solved afterwards and it will just increase the delay, to solve this problem the backoff timer calculations is modified as shown in figure 48; the modifications is highlighted and underlined; if a collision occurs in the 1^{st} retransmission the values of CW1 will be updated before calculating the backoff timer which will improve the performance of the proposed mechanism.

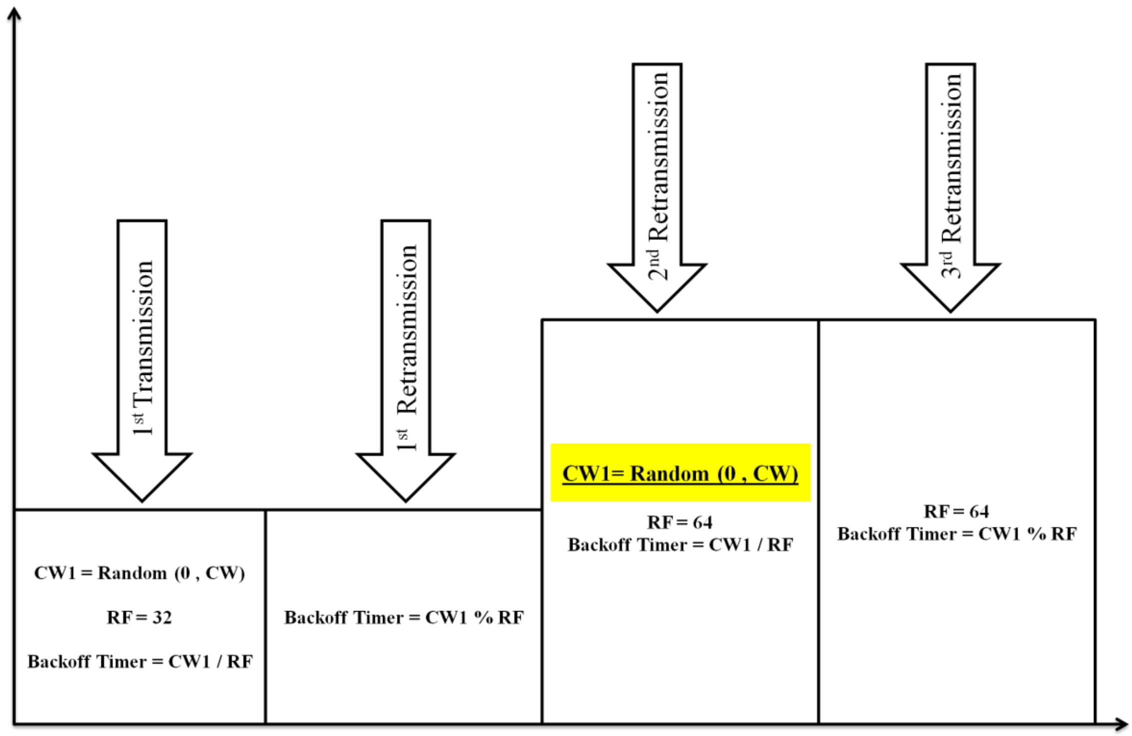

Figure 48: The modified backoff timer calculations using CW1 and RF.

The proposed mechanism can be also improved by taking into consideration the number of active stations; each station's NAV is updated whenever it hears an RTS or CTS; using the values in NAV can be used to better adjust the value of RF based on previous active transmissions.

Finally the proposed mechanism can address the Quality of Service (QoS) by introducing different categories using the RF value; the results have previously shown that the modified mechanism can successfully reduce the average jitter's values which is considered an essential improvement when transmitting real time data thus it is an important factor in QoS; addressing the QoS issues will be the main future modification on the proposed work.

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الية اطار تنافس معدلة لدالة التنسيق الموزع في معيارية ٨٠٢,١١

إعداد:
ثائر علي محمود القباعي

المُشرف:
الدكتور عباللطيف أبو دلهوم

الملخص

شبكات الاتصال اللاسلكية هي عبارة عن مجموعة من الأجهزة االمتصلة مع بعضها البعض عن طريق الانبعاثات الكهرومغناطيسية مستخدمةً الهواء كوسيلة نقل; طبيعة هذه الشبكات الموزعة و طبيعة الناقل المستخدم (الهواء) اثارت الحاجة الماسة و الضرورية للتحكم و تنظيم الية الوصول للناقل و استخدامه.

معيارية ٨٠٢,١١ للشبكات اللاسلكية تحدد دالة التنسيق الموزعة (DCF) كطريقة الوصول الأساسية للشبكة، هذه الدالة تستخدم طريقة التراجع الأسي الثنائي (BEB) لتنظيم وصول الأجهزة إلى الناقل و تقليل نسبة حدوث التصادمات بين الأجهزة التي ترغب في الإرسال; يتم هذا عن طريق التحكم في حجم اطار التنافس (CW) بين هذه الأجهزة، طريقة التراجع الأسي الثنائي تعاني من عدة مشاكل تؤدي في النهاية الى إنخفاض أداء دالة التنسيق الموزعة.

هذه الرسالة تقترح ألية إطار تنافس معدلة لحل المشاكل الموجودة في التراجع الاسي الثنائي و بالتالي تُحَسن من أداء دالة التنسيق الموزعة، نتائج المحاكاة بيَّنت ان الطريقة المقترحة تمكنت من تقليل الوقت الذي تحتاجة البينات لوصول وجهتها و تمكنت ايضاً من تقليل التفاوت في أوقات الوصول، الطريقة المقترحة تعاني من سلبية و احدة فقط الا و هي زيادة معدل حزم البيانات المهملة بعد وصولها الحد الأعلى من محاولات الإرسال; مما يؤدي الى انخفاض أداء الطريقة المقترحة من حيث الإنتاجية، ايجاد حل لهذه السلبية سيؤدي لزيادة كفاءة الطريقة المقترحة و تم وضعه كأولوية مستقبلية في تعديل الطريقة المقترحة.